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THE EFFECT OF COMBAT ON AIRCREW SUBJECTIVE READINESS AND LSO GRADES DURING OPERATION DESERT SHIELD/STORM

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The effect of operational tasking on aircrew readiness during combat operations continues to be an area of intense investigation within the U.S. Navy. The recent Persian Gulf War provided a unique opportunity to collect data examining aircrew work/rest cycles and operational tasking in a combat environment. For 4 consecutive weeks during Operations Desert Shield and Desert Storm, 18 A-6 and 18 F-14 aviators onboard the USS AMERICA (CV-66) completed daily work/rest logs of their activities while conducting operations from the Red Sea. Activities on the work/rest logs were coded to a resolution of one-half hour. Several flight parameters were also obtained including: 1) takeoff and landing time, 2) flight duration, 3) mission type, 4) consecutive days during which a flight occurred, 5) landing signal officer (LSO) scores, and 6) arresting wire engaged on landing. In addition, after each mission aircrew provided a subjective assessment of the amount of time that they needed to rest before another air-to-ground strike mission could be flown (a measure of subjective readiness). Multiple regression analysis indicates that flight duration, the number of flights per day, and the time-of-day that the flight occurred, impact heavily on subjective evaluations of aircrew readiness. Few consistent relationships were observed between the independent measures and LSO grades. The data obtained here represent a unique look at aircrew work/rest patterns as they effect aircrew readiness during armed conflict. These data provide unique and valuable information to air wing commanders and senior mission planners when tasking carrier-based aviators. In addition, these data provide an essential database for squadron and air wing flight surgeons to draw upon when assessing aircrew readiness.

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SUMMARY PAGE

THE PROBLEM

Few measures of aircrew work/rest schedules and aircrew readiness during combat operations exist. A more precise means of evaluating aircrew readiness following combat missions is necessary for senior mission planners, squadron commanding officers, and flight surgeons to assess the readiness of aircrew available for subsequent missions.

FINDINGS

The recent Persian Gulf War provided a unique opportunity to collect data examining aircrew work/rest cycles and operational tasking in a combat environment. For four consecutive weeks during Operations Desert Shield and Desert Storm, 18 A-6 and 18 F-14 aviators onboard the USS AMERICA (CV-66) completed daily work/rest logs of their activities while conducting operations from the Red Sea. Activities on the work/rest logs were coded to a resolution of one-half hour. Several flight parameters were also obtained: 1) launch and recovery time, 2) flight duration, 3) mission type, 4) consecutive days during which a flight occurred, 5) landing signal officer (LSO) scores, and 6) arresting wire engaged on landing. In addition, after each mission, aircrew provided a subjective assessment of the amount of time that they needed to rest before another air-to-ground strike mission could be flown (a measure of subjective readiness). Multiple regression analysis indicates that the flight duration, the number of flights per day, and the time of day that the flight occurred impact heavily on subjective evaluations of aircrew readiness. Multiple regression equations were derived and are presented for use when assessing aircrew readiness. Few consistent relationships were observed between the independent measures and LSO grades.

RECOMMENDATIONS

The data obtained here are intended to assist air wing commanders and senior mission planners in tasking carrier-based aviators. Squadron and air wing flight surgeons should also find the data beneficial when assessing aircrew readiness. Ultimately, when used with existing experiential and qualitative judgements by individuals charged with determining aircrew readiness, our data should prove useful in improving the safety of flight.

Acknowledgments

We would like to extend our thanks to CAPT Hill, CAPT Rogers, CAPT Dalton, and CDR Dowell for their role in the logistics of this field study. We are especially indebted to COMNAVAIRLANT, CVW-1, USS AMERICA, and the men of VA-85 and VF-102, without whose support during this time of extreme stress and sacrifice, we would not have been able to conduct this study. A special thanks is also extended to Dr. DeJohn and LCDR Shively who were instrumental in the data collection and served as members of the research team deployed aboard the USS AMERICA.

INTRODUCTION

Even with a changing geopolitical environment, the aircraft carrier remains the U.S. Navy's principal means of power projection ashore during periods of international tension. When called into combat, operations aboard aircraft carriers can range from short-duration contingency operations and surgical strikes (e.g., Libyan air strike) to limited war (e.g., Operation Desert Storm). The activity of pilots and naval flight officers (NFOs) aboard U.S. Navy aircraft carriers during such operations can be described as continuous operations (CONOPS) frequently interrupted by periods of sustained operations (SUSOPS). Aircrews in the U.S. Navy may be called on to engage in combat operations and required to sustain performance around the clock over many different time zones. These periods of SUSOPS often require many hours of mission planning and briefing by the same aircrew who later fly into combat. This 'front-loading' of naval aviators, in advance of flying, may increase the risks associated with the flight itself. However, even when naval aviators are not engaged in combat-related SUSOPS, they are not entirely free to rest in preparation for the next event. Rather, they are often required to perform numerous collateral duties, requiring long periods of CONOPS, separated by erratic opportunities for rest. The nature of such CONOPS/SUSOPS aboard an aircraft carrier frequently disrupts normal sleep patterns, often exacerbating stress and fatigue of aircrew. These disruptions could conceivably take the form of fragmented sleep, disturbances of sleep-wakefulness cycles, and circadian desynchronosis (1). Further complications result when carrier-based aircraft are launched and recovered on flight decks a fraction of the size of a conventional landing strip. Any one, or combination of these factors, may combine with high-workload schedules to impair aircrew performance and impact negatively on operational readiness.

Many articles cite the effect of extended work/rest cycles, CONOPS, and SUSOPS on human performance (for an annotated bibliography see (2), for a review see (3)). However, only a few of these reports have dealt with specific issues involving fatigue among combat aircrews (4-16). Still fewer have investigated naval aviators in their own environment (i.e., aboard an aircraft carrier) during combat or peacetime fleet exercises (7-9,11,15). A brief review of the effects of fatigue among combat aviators is presented below.

Combat aircrews routinely participate in 24-h training exercises that are designed to emulate combat CONOPS/SUSOPS. These exercises provide an ideal scenario to investigate aircrew fatigue as it relates to high-tempo operations. Storm (5) obtained subjective measures of fatigue from U.S. Air Force A-7, A-10, and F-4 aircrew while they were engaged in high-tempo opera... Called "sortie surges," these operations often require aircrew to log the equivalent of one month's flight hours in one week. A major finding was that within each day of the surge, subjective fatigue increased as a function of the number of sorties flown, but little or no circadian effects were evident. Complete recovery was reported by the start of each successive day. That subjective fatigue increases with the number of sorties flown each day is not surprising; however, the overall lack of any circadian effect was less expected. The author offers two explanations for this apparent lack of any circadian effect. First, the exercise was conducted at the aircrew's home base, which allowed them to perform in a familiar environment with comfortable sleeping arrangements. Second, all the sorties were flown between 0600 and 2300 h, which is well within a normal work day and without the influence of adverse circadian effects. Both observations limit the generalization of the findings to many combat operations. Therefore, it is possible that in an unfamiliar and hostile environment, as in combat, even higher levels of fatigue would be reported by aircrew.

In two related studies, Army helicopter pilots engaged in various flight maneuvers and flew designated flight profiles during 20-h workdays for 5 consecutive days with 3.5 h (14) and 4.0 h (6) of sleep per night, respectively. Several findings are relevant to this discussion. First, all aircrew completed the study without incident. Second, although flight performance did not degrade appreciably by the fourth day, pilots appeared to respond more passively with the flight controls. By the fourth day of the schedule, aircrew began making more errors of omission, leaving out important safety and communication checks. In fact,

Krueger et al., (6) report that the copilots in their study even took occasional naps in the cockpit when task demands were low. Therefore, for at least helicopter aircrew flying a simulator, 3.5-4 h sleep per night appears to be sufficient to maintain performance in the aircraft. However, the maintenance of such a demanding schedule may be at the cost of aircrew safety. It is not uncommon, during at-sea periods of CONOPS and SUSOPS, for naval aircrews to operate for several days with only 4-6 h of sleep in a 24-h period. Given these two studies of Army helicopter pilots, such patterns of work and rest may increase the likelihood of aircrew mishaps.

Borowsky and Wall (4) compared naval class A flight/flight related (F/FR) aircraft mishaps with several variables thought to be associated with aircrew fatigue in helicopter, fighter, and attack communities occurring during a 5-year period from 1977-1982. Seven variables were related to aircrew fatigue: 1) hours worked in the last 24/48 h, 2) missions flown in the last 24/48 h, 3) hours continuously awake before the mishap, 4) hours of continuous duty before the mishap, 5) hours duration of last sleep, 6) time in the cockpit before flight, 7) hours slept in the last 24/48 h, and 8) hours flown in the last 24/48 h. Of these, only the hours worked in the last 24/48 h was significantly related to naval aircraft mishaps. Moreover, this relationship only existed for the fighter and helicopter communities. No relationship was observed within the attack community.

In the same article, the authors attributed the general lack of significant findings to several factors, including the 'quality' of sleep and circadian desynchronization. For example, a mission with a 2400 launch and a 0400 recovery would occur when a pilot might ordinarily be asleep. In an attempt to compensate, the pilot might choose to sleep from 1400 to 2000. Although technically the period of sleep is 6 h, the quality of sleep, having occurred around a circadian peak, may be markedly reduced. The authors acknowledge that this may have compromised their results. A closer inspection of their data revealed that mishap rates were significantly related to the time of day that the flight originated. For the fighter and attack communities, flights originating between 2400 and 0600 h were associated with higher mishap rates, a time when pilot circadian rhythms would ordinarily be in a trough. Similarly, mishap rates were highest for the helicopter community between 2100 and 2400 h. In all three communities, these periods of higher mishaps rates could be attributed to circadian desynchronization or an increase in the difficulty of night, relative to daytime, flying. The authors provide support for a circadian desynchronization explanation by demonstrating that mishap rates were still high during the 0600-0900 and 1800-2100 period for the fighter and attack communities and 1800-2100 period for the helicopter community. Specifically, each of these periods coincides with sunrise or sunset, a time when the mishap rates could not be entirely attributed to day versus night flying.

Relatively few studies of combat aircrews aboard aircraft carriers have been done. Of the studies that have been done, the majority have been conducted by Brictson and his colleagues (7-11,15,16). Two of those studies warrant particular attention here. In a comprehensive review of 3 years of their research, Brictson et al., (11) discuss their findings regarding aircraft carrier landing performance in both day and night environments. Their experimental sample consisted of roughly 1800 recoveries aboard 4 aircraft carriers, using both experienced (F-4 and A-4) and inexperienced (F-8) pilots, across various environmental conditions. Accessing the shipboard instrumentation system (SPN-10), they were able to record inflight geometry of the aircraft during its final approach to landing. At night, when visual cues are minimal and the environment otherwise impoverished, pilot performance was characterized by an increase in altitude control errors, a larger percentage of carrier approaches below glide slope, and a higher rate of unsuccessful approaches. Although no practical or statistical differences were found in day and night lateral error (left or right of course) or approach speed, aircraft were more likely to land shorter on the flight deck (#1 and #2 arresting wire) by day and longer (#3 and #4 arresting wire) by night. When the landing sequence was further complicated by inclement weather (high seas and a pitching flight deck), the difference between successful landings during the day and night was exacerbated. A final comparison of landing success was made using a criterion envelope defined as $\pm\ 2\ \sigma$ values from the mean computed for both day and night successful approaches. The probability of landing success when outside the criterion envelope was much

higher during the day (100% for F-4, 90% for A-4) than at night (50% for F-4, 45% for A-4). The relationship was consistently worse for the inexperienced F-8 pilots (38% during the day, 19% during the night). These data demonstrate that even with sophisticated optical landing systems, trained landing signal officers, and experienced pilots, landing aboard an aircraft carrier at night is an extremely demanding task and vulnerable to mishaps.

In a follow-up investigation, Brictson (8) conducted a longitudinal study of pilot carrier landing performance to describe the influence of prolonged operations on pilot performance. Using a landing performance score (LPS) developed earlier (16), Brictson was able to evaluate F-4 and A-7 pilot landing performance during zero, moderate, and high levels of workload. The zero cumulative workload level consisted of pilot landings made after a prolonged nonflying period, commonly after inport operations. The moderate level of workload was defined by 11 consecutive days of flying missions over nonhostile territory. High levels of workload occurred when pilots engaged in double the moderate level of missions over hostile territory with the threat of death present.

Several findings are relevant to this discussion. First, carrier landings during the day were consistently rated higher using the LPS than were night landings. In no instance, did night LPS exceed day LPS. Second, the overall day landing performance showed a gradual but continuous increase in LPS from the beginning through the end of the deployment. Third, only the high-workload condition differentially influenced LPS during night landings. Specifically, landing performance aboard the carrier at night only improved during a period when 22 consecutive days of flying had occurred. The authors concluded that the cumulative increase in LPS observed during the day and night could be attributed to practice effects. In fact, the observation that night LPS increased only during the high-workload condition (i.e., experience acquired at night over 22 consecutive days) lends support to the practice effect hypothesis.

Whether or not practice effects can account for Brictson's findings, the feeling among most naval aviators is that landing proficiency clearly has some relationship with the number and frequency of aircraft carrier landings made during the day and night. This relationship is reflected in the U.S. Navy's requirements for pilots landing aboard aircraft carriers (NAVAIR 00-80T-104). All naval pilots must demonstrate proficiency and remain qualified in landing aboard the aircraft carrier during day and night operations. To remain qualified for day landings aboard the aircraft carrier, each pilot must have at least one arrested landing every 14 days. If the pilot goes more than 14 days without a day-arrested landing, additional refresher training is required. As might be expected, aircraft carrier qualification (CQ) at night is much more demanding. Initial night CQ requires a minimum of two day landings and one night arrested landing to qualify at night. After initial night CQ, a minimum of one night landing every 7 days is required to maintain proficiency.

When aircrew are tasked to fly a combat mission, they are expected to execute their orders and fly the mission unless completely unable on a physical and mental basis. The preceding reports provide senior mission planners, carrier airwing commanders, squadron commanding officers, and flight surgeons with the foundation for making initial assessments of aircrew readiness. Nonetheless, many questions remain unanswered in the operational setting. What specific variables affect aircrew readiness? How does the duration of a flight influence aircrew readiness? Does aircrew readiness fluctuate with the time of day that a flight occurs? How are aircrew affected when they are required to fly multiple sorties over several days as might be expected in a long-duration contingency operation or an Eastern European war scenario? What is the necessary amount of time aircrew should sleep before flying a combat mission? Given information about operational tasking and the aircrew being tasked, is it possible to identify any variables that would aid in the prediction of aircrew readiness?

METHODS

The Persian Gulf War provided a unique opportunity to document work/rest cycles as they relate to operational requirements and aircrew readiness in a combat situation. For the U.S. Navy, this meant deploying aboard an aircraft carrier enroute to the Red Sea or Persian Gulf operating areas. Deciding which aircrew to investigate was difficult. There are currently seven different carrier-based aircraft, each with their own unique mission and specialized aircrew. These include 1) A-6 Intruder, 2) F-14 Tomcat, 3) F/A-18 Hornet, 4) E-2 Hawkeye, 5) EA-6 Prowler, 6) S-3 Viking, and 7) SH-3 Sea King. Since a complete investigation of aircrew associated with all seven carrier based aircraft was not possible, we chose to limit our investigation to one attack squadron (A-6 Intruder) and one fighter squadron (F-14 Tomcat).

SUBJECTS

Aircrew were recruited from one A-6 Intruder squadron (VA-85) and one F-14 Tomcat squadron (VF-102) assigned to Carrier Air Wing 1 (CVW-1) deployed aboard USS AMERICA during Operations Desert Shield and Desert Storm. The A-6 Intruder is a two-seat aircraft and requires a pilot and bombardier/navigator (B/N) to complete its mission. Also a two-seat aircraft, the F-14 Tomcat requires a pilot and radar intercept officer (RIO). The experimental subjects included 18 volunteers from VA-85 (9 pilots and 9 B/Ns) and 18 volunteers from VF-102 (10 pilots and 8 RIOs). The subjects varied in rank from ensign to commander and age from 25 to 37 years old with a mean age of 29.3 years. The data collection was conducted during peacetime operations (Operation Desert Shield) and while at war (Operation Desert Storm), and all subjects were routinely briefed regarding the voluntary nature of the study and permitted to withdraw without prejudice.

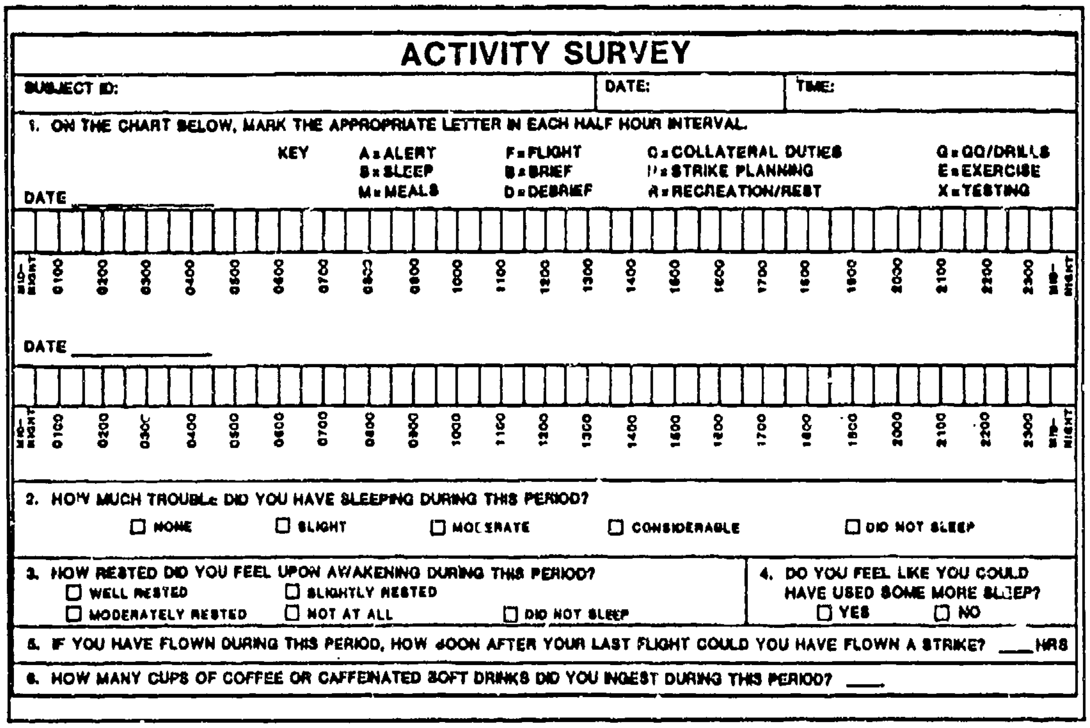
PROCEDURE

Our goal was to document aircrew work/rest cycles as they relate to aircrew readiness and landing proficiency during training and actual combat. A secondary aim was to identify any variables that would aid in the prediction of aircrew combat readiness and landing signal officer (LSO) grades. Toward these ends, all subjects completed a daily activity survey including questions regarding the quality of sleep and combat readiness. Additional data identifying operational tasking and LSO grades were obtained from the squadron operations officer.

Data collection was from 03 January 1991 for A-6 aircrew and 05 January 1991 for F-14 aircrew through 04 February 1991; 2 weeks during Operation Desert Shield (Jan 3 - Jan 16) and 2.5 weeks during Operation Desert Storm (Jan 17 - Feb 4). This enabled comparisons to be made between aircrew engaged in training exercises during the latter days of Operation Desert Shield and the same aircrew operating in combat situations during Desert Storm. The data collection during Operation Desert Shield occurred while the USS AMERICA transited the Atlantic Ocean and Mediterranean Sea enroute for the northern Red Sea. All data collection during Operation Desert Storm occurred while the USS AMERICA was positioned on station in the northern Red Sea.

Subjects completed a daily activity survey (Fig. 1), which was an adaptation of the survey designed by the U.S. Air Force School of Aerospace Medicine (17). Subjects were instructed to indicate their activity to a resolution of 0.5 h by marking in the appropriate box the letter corresponding to the activity they engaged in during that block of time. Subjects typically entered information on the survey two-three times per day, accounting for several hours at a time. Although various activities were reported by subjects, we only consider here the flight data (designated with an 'F' on the survey) and sleep data (designated with an 'S' on the survey) as it relates to flying. Flight data were used to confirm flight parameters such as launch and recovery times, flight duration, and the time of day that the flight occurred. Similarly, sleep data were used

only to identify the total amount of sleep 6, 12, 18 and 24 h before a mission. The work/rest data are presented in more detail elsewhere (18).



ACTIVITY SURVEY

SUBJECT ID: | DATE: | TIME:

1. ON THE CHART BELOW, MARK THE APPROPRIATE LETTER IN EACH HALF HOUR INTERVAL.

KEY: A=ALERT, S=SLEEP, M=MEALS, F=FLIGHT, B=BRIEF, D=DEBRIEF, C=COLLATERAL DUTIES, P=STRIKE PLANNING, R=RECREATION/REST, Q=GQ/DRILLS, E=EXERCISE, X=TESTING

DATE ______

MID-NIGHT 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 MID-NIGHT

DATE ______

MID-NIGHT 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 MID-NIGHT

2. HOW MUCH TROUBLE DID YOU HAVE SLEEPING DURING THIS PERIOD?
☐ NONE ☐ SLIGHT ☐ MODERATE ☐ CONSIDERABLE ☐ DID NOT SLEEP

3. HOW RESTED DID YOU FEEL UPON AWAKENING DURING THIS PERIOD?
☐ WELL RESTED ☐ SLIGHTLY RESTED ☐ MODERATELY RESTED ☐ NOT AT ALL ☐ DID NOT SLEEP

4. DO YOU FEEL LIKE YOU COULD HAVE USED SOME MORE SLEEP?
☐ YES ☐ NO

5. IF YOU HAVE FLOWN DURING THIS PERIOD, HOW SOON AFTER YOUR LAST FLIGHT COULD YOU HAVE FLOWN A STRIKE? ____HRS

6. HOW MANY CUPS OF COFFEE OR CAFFEINATED SOFT DRINKS DID YOU INGEST DURING THIS PERIOD? ____

Figure 1. The activity survey.

In addition to the activity data, several questions regarding sleep quality, restedness, caffeine intake, and subjective readiness were included. Items 2, 3, 4 and 6 of the activity survey are examined in the companion report (18), however item 5, "If you have flown during this period, how soon after your last flight could you have flown a strike?" is applicable here. Because subjects were instructed to answer this item immediately after a flight, it served as a subjective measure of aircrew readiness. Specifically, the item was an index of how much rest aircrew felt they needed before a _combat_ strike could be successfully flown. It was stressed to all subjects that this was not just any flight, but an actual _combat_ strike. We will refer to the data obtained from item 5 as aircrew subjective strike delay (SSD).

The only measure of aircrew performance available was the LSO grades. All landings aboard U.S. aircraft carriers are controlled by the LSO. In the U.S. Navy, LSOs are typically either pilots assigned to specific squadrons within the carrier air wing or LSOs appointed directly to the staff of the commander of the Carrier Air Group. They are educated on what is, and more importantly, what is not, a safe approach to the aircraft carrier deck. Using visual signals and voice communications, the LSO plays an integral role during the landing sequence. All aircraft carrier approaches (whether or not they end with an arrested landing) are assigned a score by the LSO ranging from 1 to 4:

1 = unsafe landing; a pilot successfully lands the aircraft but puts the aircraft or aircraft carrier at unnecessary risk.

2 = technique waveoff; the pilot is flying sufficiently outside of prescribed parameters that a safe landing is in doubt. The pilot is waved-off from landing and required to make another approach.

2.5 = bolter; when the aircraft touches down on the aircraft carrier deck, but no arresting wire is engaged, resulting in an aborted landing.

3 = fair pass; when a safe landing aboard the aircraft carrier is accomplished but the approach was less than ideal.

4 = good pass; when a safe landing aboard the aircraft carrier is accomplished and the approach was within parameters.

Albeit subjective, LSO grades, are the only means of grading pilot performance when landing aboard the aircraft carrier.

Flight information was obtained by comparing the activity survey flight data with the flight scheduling information provided by the squadron operations officer. The flight data included 1) launch and recovery times, 2) flight duration, 3) mission assignment, 4) the number and order of flights flown each day, 5) the number of consecutive days during which a flight occurred, and 6) the flight time quartile. Most of these variables are self-explanatory; however, flight time quartile requires some explanation. To evaluate if time of day had any effect on SSD or LSO grades, time of day was partitioned into four equal flight time quartiles:

Quartile 1 - 0601 through 1200
Quartile 2 - 1201 through 1800
Quartile 3 - 1801 through 2400
Quartile 4 - 0001 through 0600

If a flight sp[illegible] more than one quartile, assignments were made on the basis of that quartile in which the majority of t[illegible]ht occurred. Table 1 presents all the variables included in this study.

TABLE 1. Study Variables.

Dependent Variables	Independent Variables
Strike Delay	**War Phase**
LSO Grades	Desert Shield
	Desert Storm
	Sleep Patterns
	Sleep Prior to Mission
	06 h
	12 h
	18 h
	24 h
	Operational (Flight) Tasking
	Mission Assignment
	Flight Quartile
	Launch Time
	Recovery Time
	Flight Duration
	Consecutive Flying Days
	Number and Order of Flights Per Day

DATA ANALYSES

The data obtained from the A-6 and F-14 aircrew were submitted to two levels of analysis. Initially the data were analyzed descriptively, and meaningful relationships were plotted. The second level of analysis involved the use of multiple regression techniques to reveal any predictable pattern among the variables.

Multiple regression was used here for several reasons. First, a more complete interpretation of the dependent variables (SSD and LSO grades) is possible when using multiple regression, because these variables are quite possibly the result of more than a single cause. Second, any influence a particular independent variable may have on the dependent measure is made more certain with multiple regression techniques, as the confounding influence of other variables is eliminated. Finally, the operational community (senior mission planners and squadron flight surgeons) is particularly interested in being able to predict combat aircrew readiness (SSD) and pilot performance given specific flight and work/rest variables. Multiple regression techniques provide a metric to predict values of the dependent variable given values of the independent variables.

The general multiple regression equation expresses the dependent variable as a linear function of more than one independent variable. The general multiple regression equation can be represented as

$$Y = a_0 + b_1X_1 + b_2X_2 ... + b_iX_i + e$$

where Y is the dependent variable, a_0 is a constant, b is the partial slope associated with the independent variable, X is the independent variable, and e is the error associated with the multiple regression.

It is often useful to evaluate the relative importance of each independent variable with the dependent variable. However, in many instances it does not make sense to compare the relative magnitude of the partial slopes. Consider the following example. If we were interested in comparing the relative contribution of flight duration (measured in hours) and the number of flights per day on LSO grades, it would be problematic to compare hours to the number of flights because the measurement units are not comparable. However, it is possible to standardize the variables before any comparison. The most common way of standardizing a variable is to convert it to standard deviation units from the mean. When this is done, a new equation is formed

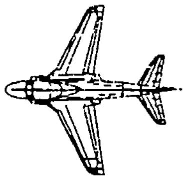
$$Y = a_0 + \beta_1X_1 + \beta_2X_2 ... + \beta_iX_i + S_e$$

where Y is now the standardized dependent variable, X is the standardized independent variable, β is the standardized partial slope, and S_e is the standardized error associated with the multiple regression. The standardized partial slope (β) is often referred to in the literature as the *beta weight* or *beta coefficient*.

In addition to the predictability of the multiple regression equation, it is also possible to assess the "goodness of fit" of the multiple regression equation by assessing the coefficient of multiple determination (R^2). Specifically, R^2 indicates the proportion of variance in the dependent variable, Y, accounted for by the independent variables, X_i. For example, if $R^2 = 0.50$, then 50% of the total variance associated with Y can be accounted for by the independent variables in the regression equation. The remaining 50% may not be readily accessible to the researcher or is otherwise unknown.

RESULTS

A-6 INTRUDER AIRCREW



Operational Tasking

A-6 aircrew were tasked quite differently during Operations Desert Shield and Desert Storm. During Operation Desert Shield, aircrew flew primarily training (TRG) and inflight refueling/tanking (TNK) missions. Included among the TRG missions, both the pilot and B/N flew a variety of missions: counter-targeting (CTTG), suppression of enemy air defenses (SEAD), precision bombing practice (BMB) and a brief war-at-sea exercise (WASEX). When not involved in TRG flights, most A-6 aircrew participated in TNK flights to provide inflight refueling for elements of the carrier air wing. In addition to the TRG and TNK flights, all pilots were required to demonstrate proficiency in both day and night recoveries. These aircraft carrier qualifications (CQ) are flight operations dedicated to multiple touch-and-go and arrested recoveries. All A-6 pilots in the study participated in CQ during the first few days following the arrival of the carrier air wing aboard the USS AMERICA. Because CQ took place 2 days before the beginning of the data collection period, it was not included in this study. Following the initial CQ period, pilots maintained recovery proficiency during normal air operations.

Operational tasking in Desert Storm differed significantly from that during Desert Shield in both flight duration and the degree of threat from the enemy. Three different missions were flown by the A-6 squadron during Desert Storm: (1) air-to-ground strike (STRIKE) missions; (2) TNK missions that accompanied the STRIKE package, called mission tanking (MSNTNK); and (3) TNK missions similar to those flown during Operation Desert Shield in support of the carrier air wing. Unlike the relatively shorter duration TRG, TNK, and CQ missions, the STRIKE and MSNTNK missions flown during Operation Desert Storm were significantly longer (4-7 h). Furthermore, both STRIKE and MSNTNK missions involved flights into enemy airspace that subjected aircrew to a large surface-to-air threat (anti-aircraft artillery and surface-to-air missiles) throughout the war.

Descriptive Statistics

Using the flight data obtained from the activity survey, combined with daily flight schedules, we reconstructed a chronology of the flights flown by A-6 aircrew during Operations Desert Shield/Storm (Fig. 2). By plotting the number of flight responses made by <u>all</u> A-6 aircrew (as indicated by an "F" on the activity survey), against the time of day, the histogram illustrates at what times aircrew were engaged in flight activities. To compare histograms within Fig. 2, flight frequency is plotted relative to the maximum frequency of "F" responses for that histogram. Relative flight frequency during the latter days of Operation Desert Shield as the USS AMERICA transited the Atlantic Ocean and Mediterranean Sea and arrived on station in the northern Red Sea is shown in Fig. 2a. In general, when aircrew were flying during Operation Desert Shield, few if any of the flights occurred outside the confines of an ordinary work day. During the transit, TRG and TNK flights occurred primarily during the late morning and afternoon hours as exhibited

by the peaks occurring at approximately 1000 and 1600 h, respectively. In contrast, little flight activity was reported between 2400 h and 0500 h, a time when most aircrew reported sleeping.

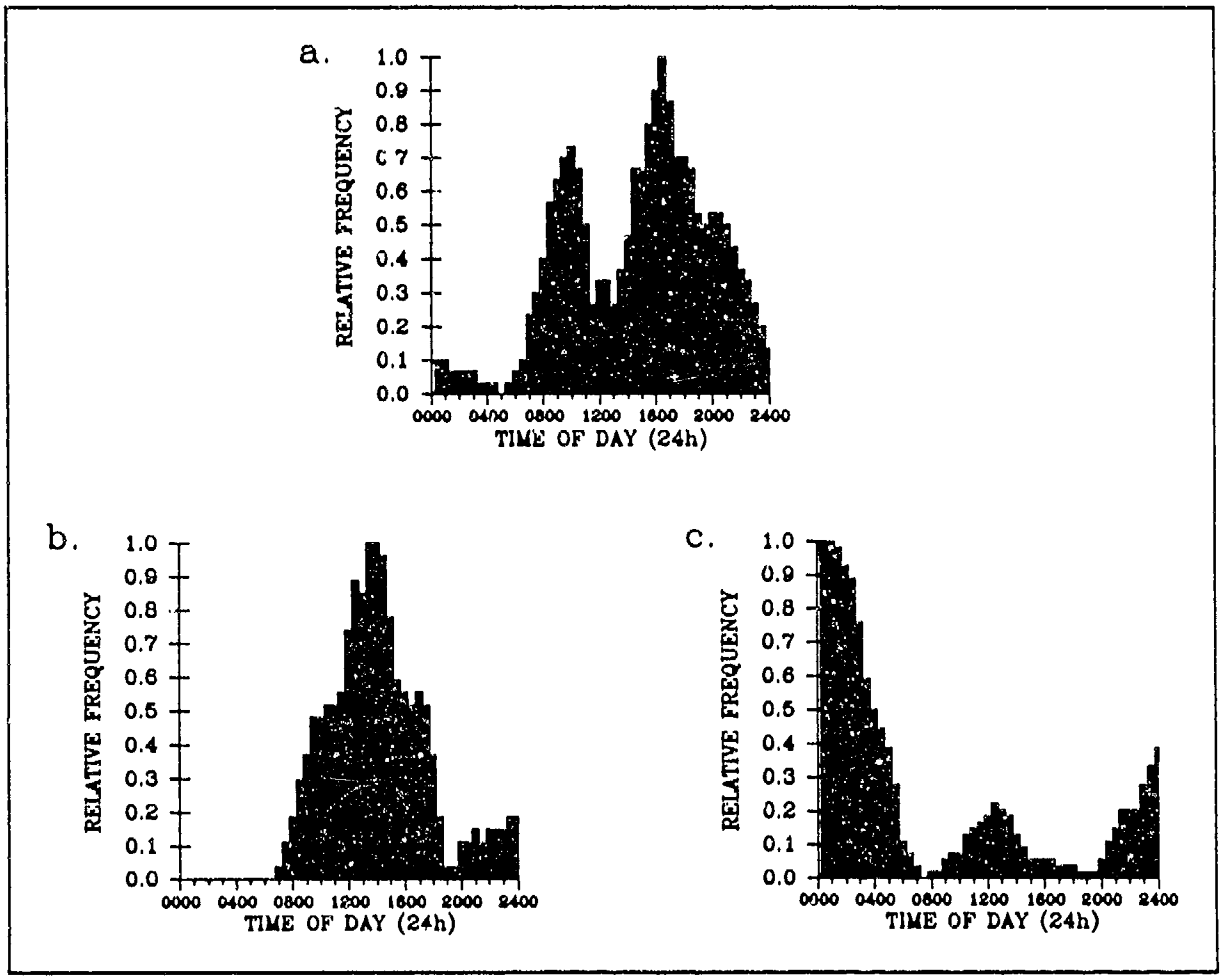


Figure 2. A-6 aircrew relative flight frequency histograms. Operation Desert Shield (a), Operation Desert Storm day flights (b), and Operation Desert Storm night flights (c).

As anticipated, with the start of Operation Desert Storm, the time of day that aircrew were flying changed as operational demands placed on the aircrew shifted from a training to a combat mode. The change in operational demands manifested itself with a marked increase in flights occurring between 2400 h and 0500 h, a time when the A-6 was used to conduct night combat strikes. To illustrate this difference, those days during which a day flight occurred (Fig. 2b) have been plotted separately from those days during which night flights occurred (Fig. 2c). Based on results from Neri and Shappell (18), a flight was considered a night flight if any portion of the flight occurred between 2400 h and 0600 h, a period when aircrew would normally be asleep.

During Operation Desert Storm daytime flight operations, A-6 aircrew flew primarily TNK missions in support of late morning and afternoon strike missions (Fig. 2b). These A-6 TNK missions were of 1-4 h duration with a peak around 1300 h, indicating that the largest relative proportion of the flying occurred then. A second, much smaller peak, occurring between 2000 and 2400 h is also apparent in Fig. 2b. The

second peak reflects the infrequent occurrence of a second flight later that evening, which was typically another TNK flight in support of the night strike flown by A-6 and other support aircrew.

The primary role of A-6 aircrew during night operations was inflight MSNTNK and air-to-ground STRIKE missions. In general, the MSNTNK and STRIKE missions were 5-7 h long occurring between 2100 and 0500 h (Fig. 2c). Clearly, these night missions impacted heavily on normal sleep patterns. In fact, Neri and Shappell, (18), confirmed that these night strike missions often delayed the normal sleep period onset an average of 4-h. Similar to the day flights during Operation Desert Storm, night flights were occasionally followed by a second, short-duration (1-3 h) TNK mission. This is exhibited by the second, smaller peak, in Fig. 2c.

A unique feature of this field study was the ability to investigate what effect operational tasking had on aircrew readiness by evaluating its effect on SSD. As expected, those missions that involved flights into enemy airspace (i.e. MSNTNK and STRIKE missions) were associated with a higher SSD than TRG and TNK missions (Fig. 3). In general, TRG missions were associated with the least need for crew rest as indicated by aircrew SSD responses, followed by TNK, MSNTNK, and STRIKE missions, in that order. On the average, aircrew reported needing a minimum of 5 h crew rest following TRG missions before they felt capable of flying a combat STRIKE, and 9-12 h crew rest following a STRIKE mission. No consistent differences were observed in the pattern of responses reported by pilots (Fig. 3a) and B/Ns (Fig. 3b). Although operational tasking does appear to influence aircrew SSD, this effect may be more a function of the duration of the flight. Those flights associated with longer SSDs (i.e., MSNTNK and STRIKE missions) were of longer duration as well (Table 2). It was not possible to separate the effects of operational tasking from flight duration. Figure 4 presents the flight duration data separately as it relates to aircrew SSD. Both pilot (Fig. 4a) and B/N (Fig. 4b) SSD were observed to increase as a function of flight duration. Average SSD ranged from a minimum of 1-2 h following a 1-h flight to as much as 8-15 h following flights of more than 7 h. No marked differences were observed between the pilot and B/N SSD.

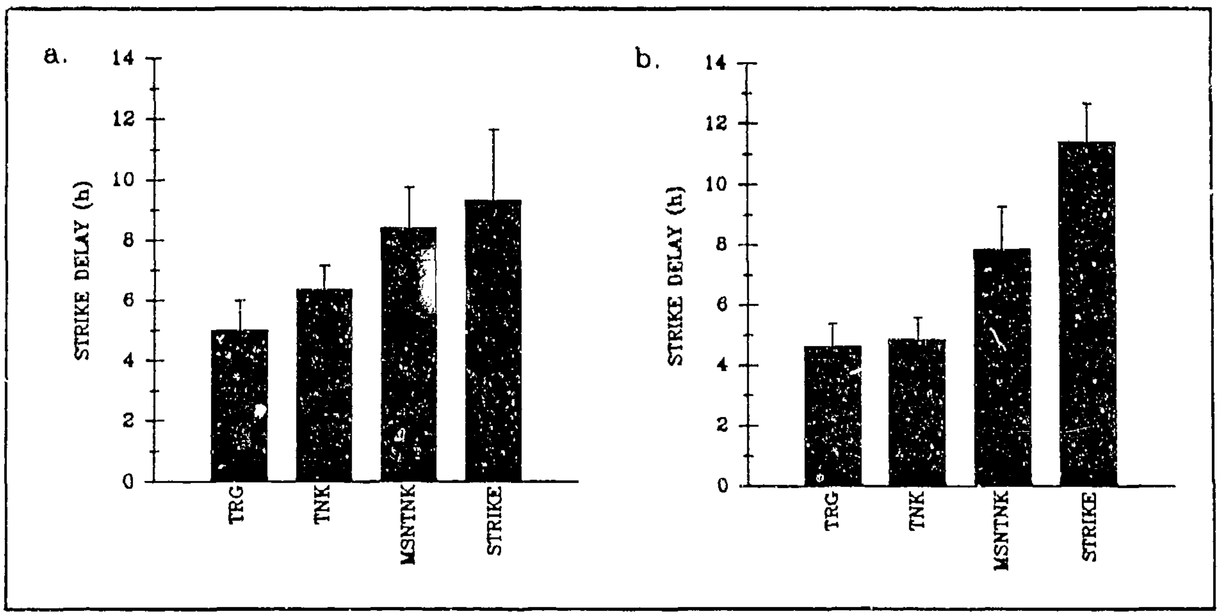


Figure 3. A-6 pilot (a) and B/N (b) mean SSD (+ 1 *SEM*) plotted as a function of mission type.

TABLE 2. A-6 Aircrew Flight Duration Descriptive Statistics

	Mission			
Statistics	TRG	TNK	MSNTNK	STRIKE
Minimum	1.5	1.0	1.5	2.5
Maximum	5.5	6.0	8.0	9.5
Mean	3.115	2.941	4.404	5.656
SD	0.796	0.963	2.034	1.505

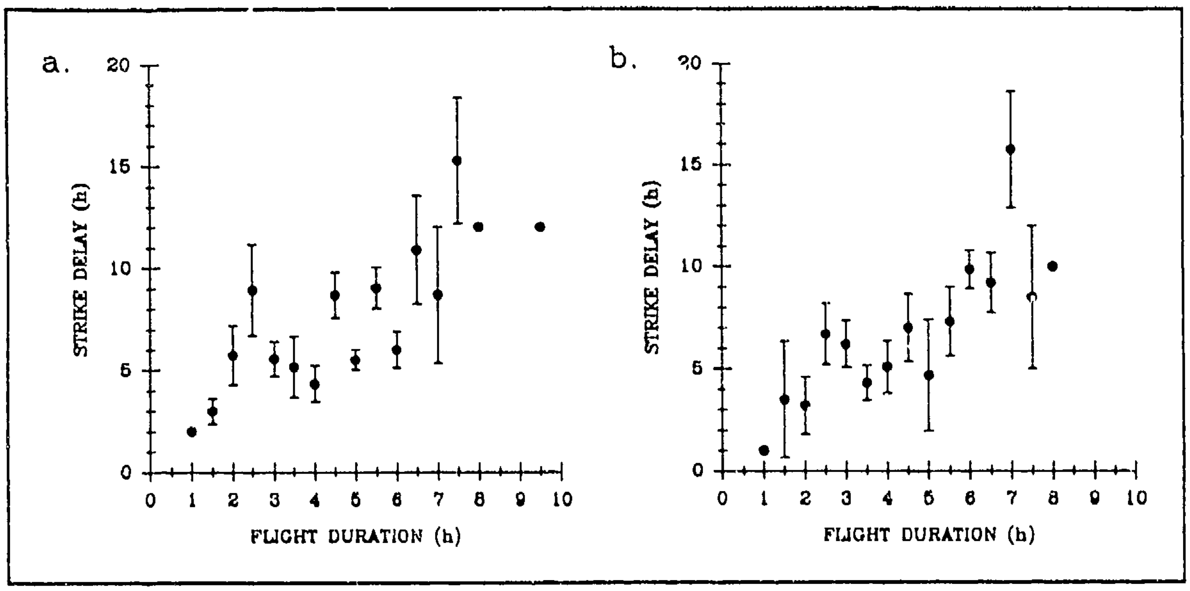


Figure 4. A-6 pilot (a) and B/N (b) mean SSD (± 1 *SEM*) plotted as a function of flight duration.

Several additional flight parameters were investigated as they relate to SSD including flight quartile, the number and order of flights in a day, and consecutive days during which a flight occurred. The time of day that a flight occurred appears to have had an impact on pilot and B/N SSD (Fig. 5). Both aircrew reported the longest SSD following flights that occurred during the fourth flight quartile (0001-0600 h). However, there were noticeable differences between the pilot and B/N groups regarding the other three flight quartiles. For the A-6 pilots, the reported SSD was similar for the third (1801-2400 h) and fourth (0001-0600 h) flight quartiles, suggesting that the two quartiles were not perceived differently (Fig. 5a). In contrast, B/Ns reported the lowest SSD scores during the second and third (1801-2400 h) flight quartile (Fig. 5b). Both groups reported progressively lower scores during the first (0601-1200 h) and second (1201-1800 h) flight quartiles, respectively.

Somewhat unexpectedly, the number and order of flights occurring per day appeared to only affect pilot SSD. On the average, pilot SSD was higher following the second, relative to the first, flight of the day (Fig. 6a). In fact, the reported SSD for the second flight was nearly twice that of the first. Little or no apparent differences were observed between the first and second flight of the day for B/Ns (Fig. 6a). Unlike

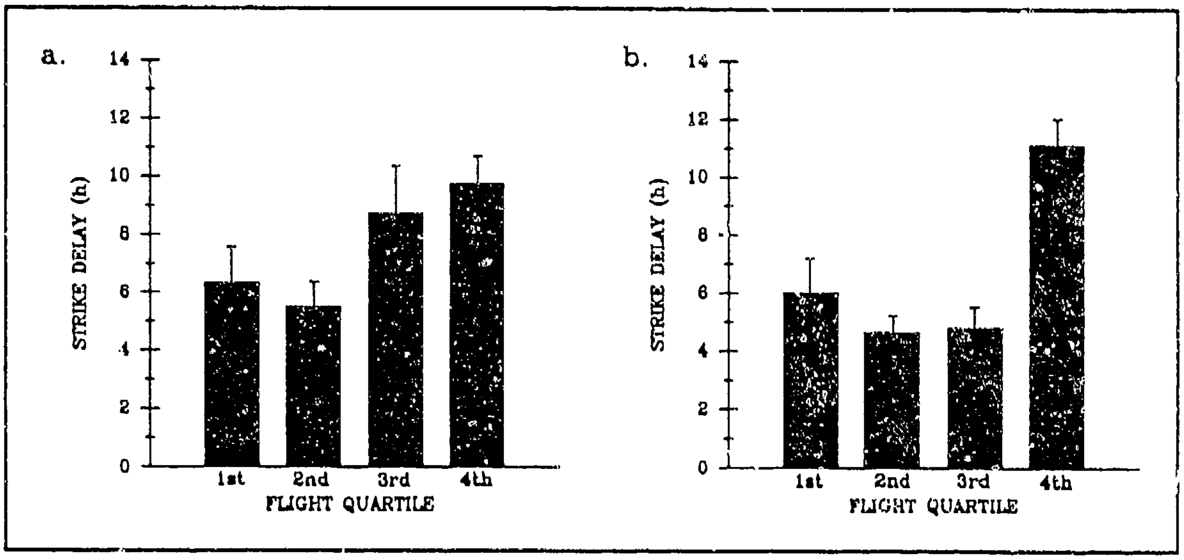


Figure 5. A-6 pilot (a) and B/N (b) mean SSD (+ 1 *SEM*) plotted as a function of flight quartile.

their pilot counterparts, B/Ns do not appear to suffer from any cumulative effects attributed to the number of flights occurring in a day.

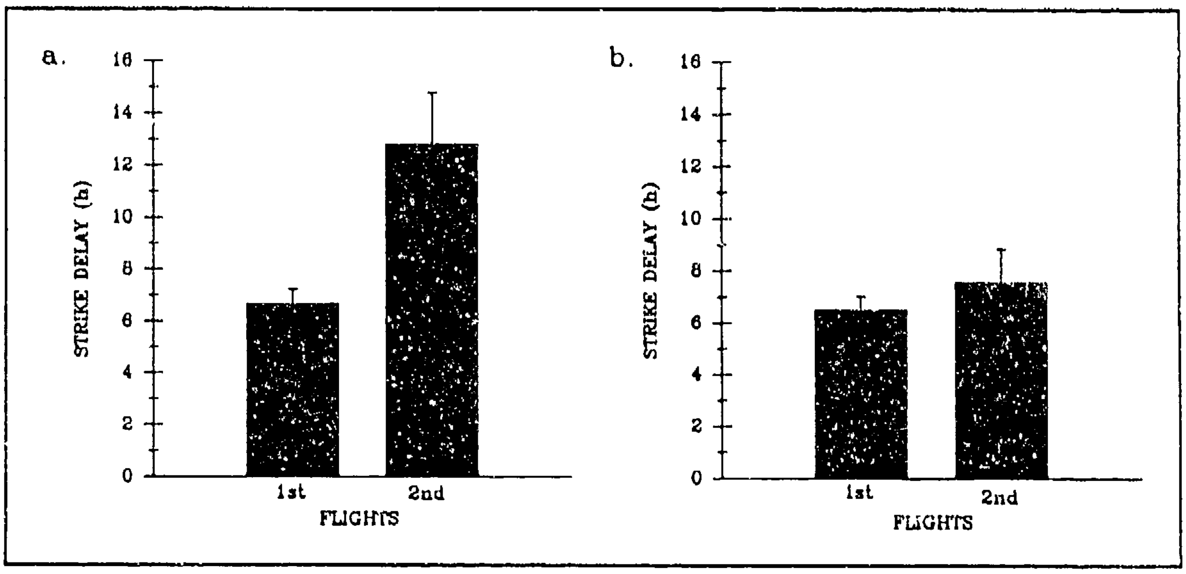


Figure 6. A-6 pilot (a) and B/N (b) mean SSD (+ 1 *SEM*) plotted as a function of the number and order of flights in a day (24 h).

The number of consecutive flight days also differentially affected pilot and B/N SSD (Fig. 7). Both aircrews reported the longest SSD on the third consecutive day during which a flight occurred. However, pilot SSD appeared to increase progressively up to three consecutive days (Fig. 7a). On the first two successive flight days B/N SSD was nearly identical and then increased markedly on the third consecutive day of flight (Fig. 7b). Curiously, both pilots and B/Ns showed a marked reduction in SSD following the fourth, relative to the third, consecutive flight day. This apparent reduction, following four consecutive flight

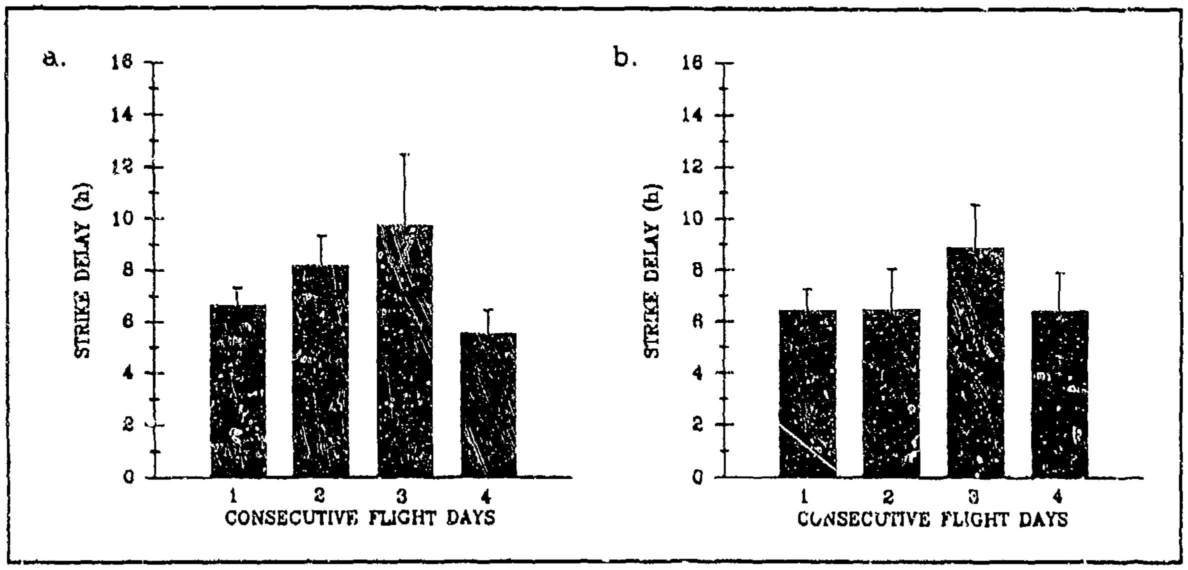


Figure 7. A-6 pilot (a) and B/N (b) mean SSD (+ 1 *SEM*) plotted as a function of the number of consecutive flight days.

days, may be somewhat artificial since long-duration MSNTNK and STRIKE missions were generally only flown during the first three consecutive flight days. Consecutive flight day four usually involved a short-duration TRG or TNK flight. Such a bias may reflect attempts made by the operations officer to schedule aircrew for less stressful TNK missions following three consecutive flight days and might have artificially deflated the SSD score on consecutive flight day four.

As anticipated, the amount of sleep A-6 pilots (Fig. 8) and B/Ns (Fig. 9) obtained before engaging in flight activities influenced reported SSD. For both pilots and B/Ns, five out of eight prior sleep periods examined revealed a decrease in SSD as the amount of time spent sleeping increased. The only exceptions were observed 18 and 24 h before the flight for pilots and 24 h before the flight for B/Ns. Furthermore, with only a few exceptions for pilots, all aircrew received some rest before engaging in flight activities. What these figures do not illustrate is whether or not the sleep was fragmented or represents a solid block of sleep activity. Examination of the raw data indicates that the latter is more likely. In fact, most aircrew engaged in 4-11 h of sleep activity in the 24-h period before flying (Figs. 8d and 9d), an amount well within, or even exceeding, what might be expected given the stressful conditions these aircrew were faced with. Even when pilots reported little or no sleep 18 and 24 h before a flight, their SSD was only 6 h, which is well below that of flights with considerably more sleep before launch. With the few exceptions noted earlier, the results indicate few differences in SSD as a function of prior sleep for pilots and B/Ns.

We compared LSO grades assigned to A-6 pilots to flight duration (Fig. 10a), flight quartile (Fig. 10b), the number and order of flights occurring in a day (Fig. 10c), and consecutive flight days (Fig. 10d). Mean LSO grades were high; from 3 (*fair pass*) to 4 (*good pass*). Although the LSO grades did not vary consistently across any of the flight variables, they increased slightly as a function of the number and order of flights per day (Fig. 10c) and consecutive flight days (Fig. 10d). The A-6 pilots received higher grades on the second of two flights during the day. A consistent increase was also evident as the number of consecutive days during which a flight occurred increased over four consecutive days.

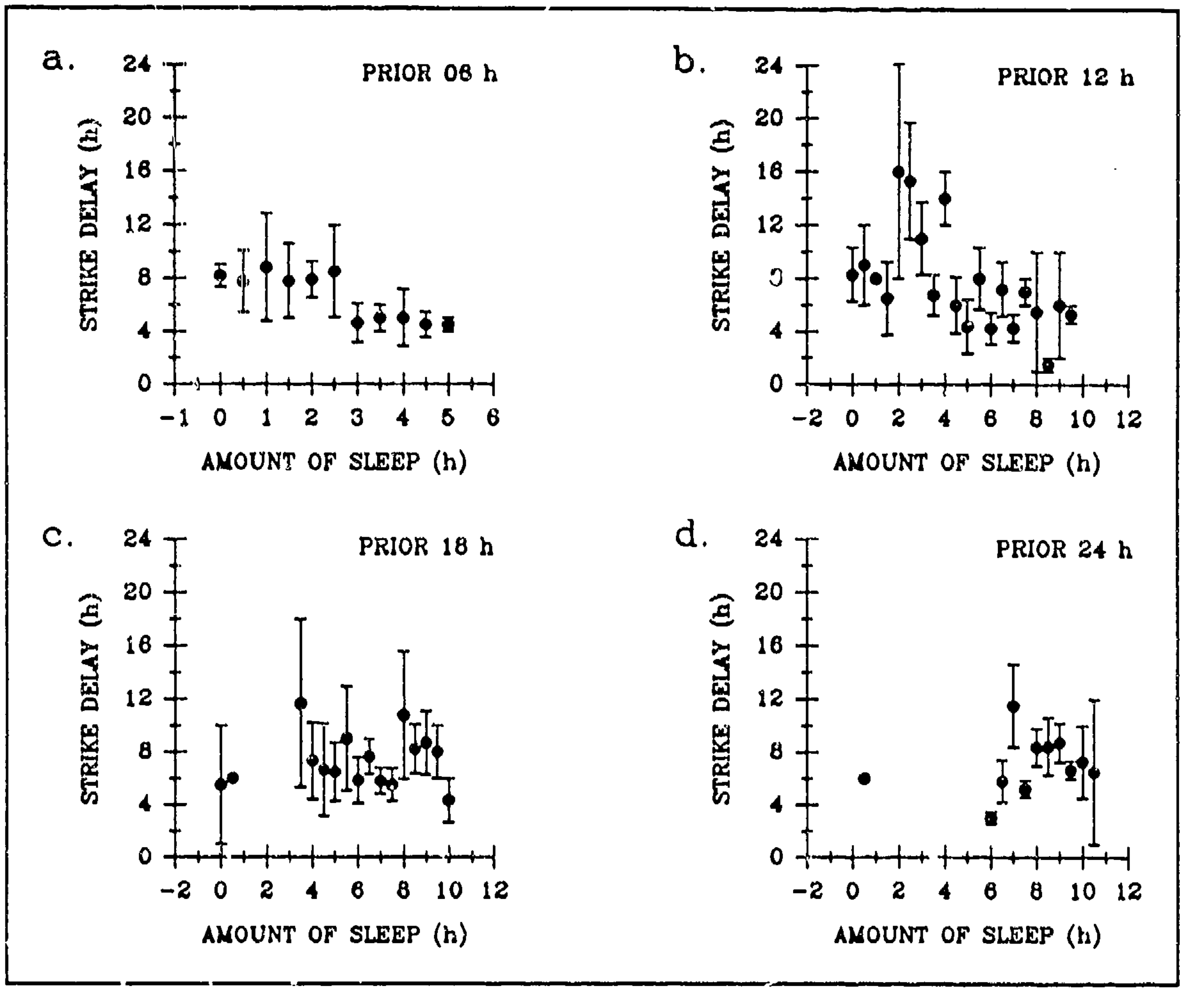


Figure 8. A-6 pilot mean SSD (± 1 *SEM*) plotted as a function of the amount of sleep 06 h (a), 12 h (b), 18 h (c), and 24 h (d) prior to flying.

Multiple Regression

A liberal significance level (p) of .10 was adopted because our main concern was to increase power and reduce type-II error. Due in part to the unique nature of the data, and the fact that the data were obtained in the field during a war, the importance of detecting the presence of any changes in SSD was considered greater than the risk of falsely rejecting the null hypothesis of no change. Thus, avoiding type-II error was considered more important than committing type-I error. The results of the multiple regression analysis are presented in Tables 3, 4, and 5. A significant multiple regression was obtained for A-6 pilots (Table 3). Using the significant regression coefficients in Table 4, the multiple regression equation could be represented as follows:

$$\mathbf{SSD_{A\text{-}6Pilots} = 0 + 1.036\ (Flight\ duration) + 4.765\ (Flight\ number)}$$

As shown in Table 3, using this equation, 21.4% of the variance can be accounted for. The adjusted multiple R^2 represents the variance accounted for given a new sample from the population. In this instance, the

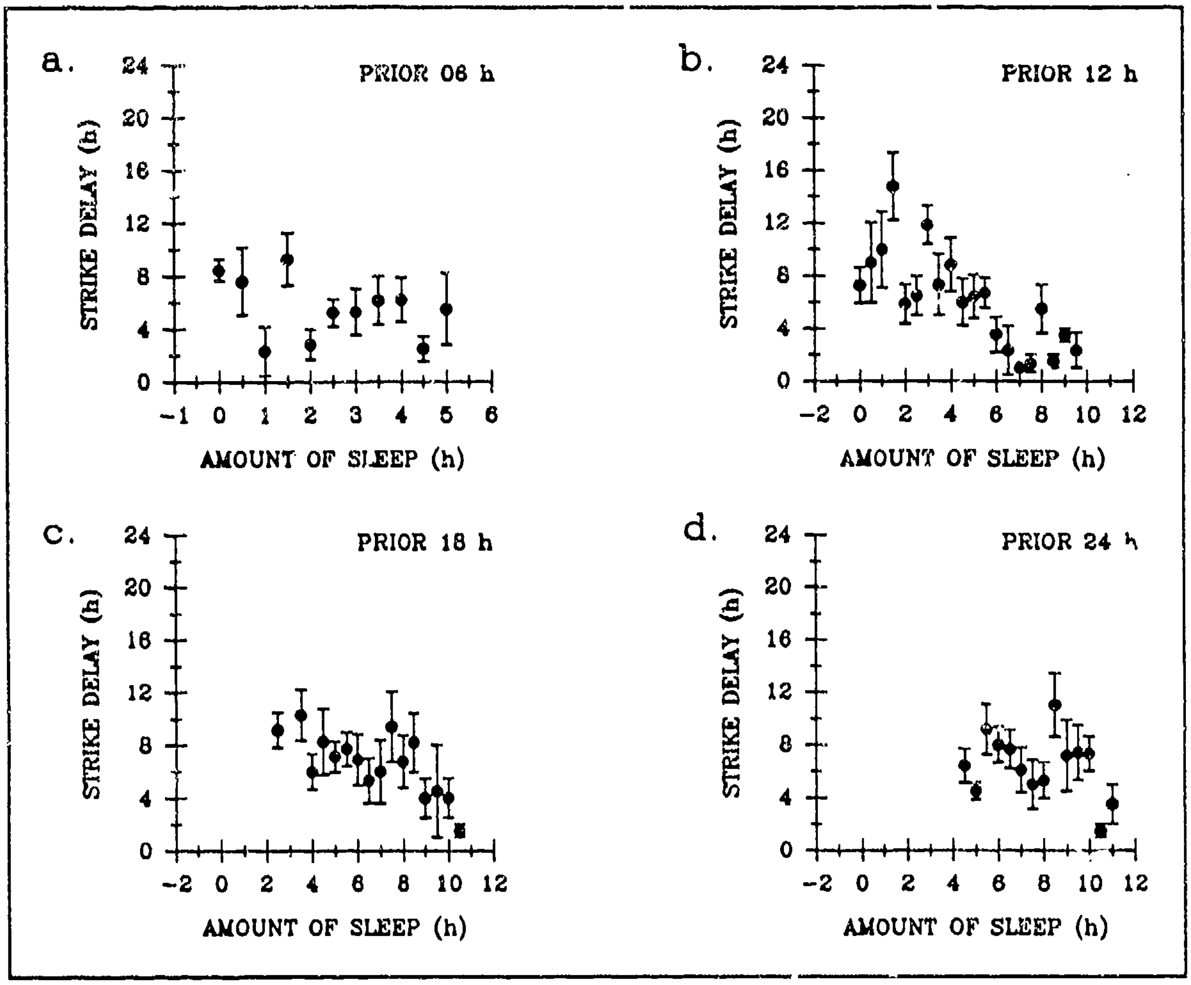


Figure 9. A-6 B/N mean SSD (± 1 *SEM*) plotted as a function of the amount of sleep 06 h (a), 12 h (b), 18 h (c), and 24 h (d) prior to flying.

predicted variance that could be accounted for using this equation given a new sample from the population is 19.6%. The standard coefficients (beta weights) have been provided in Table 4 to compare the relative contributions of the significant variables. For A-6 pilots, flight duration shows the strongest relationship with SSD followed by the number and order of flights per day.

A significant multiple regression was also obtained for A-6 B/Ns (Table 3). Using the significant regression coefficients in Table 5, the multiple regression equation can be represented as follows:

$$\mathbf{SSD}_{\mathbf{A\text{-}6\ B/Ns}} = \mathbf{3.809 + 0.743\ (Flight\ duration) + 0.866\ (Flight\ quartile) - 0.276\ (sleep\ 12\ h\ before\ flight)}$$

By using this equation, the variance accounted for is 31.1%, with the predicted variance accounted for given a new sample from the population being 28.9%. The standard coefficients have been provided in Table 5 to compare the relative contributions of the significant variables. For A-6 B/Ns, sleep 12 h prior to the flight shows the strongest relationship with SSD followed by flight duration and flight quartile, respectively. Unlike the A-6 pilots, a significant constant of 3.8 h was obtained. This result indicate that with all else equal, A-6 B/Ns report needing roughly 4 h more crew rest than their pilot counterparts.

TABLE 3. A-6 Aircrew Multiple Regression Results.

Aircrew	N	Multiple R	Multiple R^2	Adjusted multiple R^2	S_e	ANOVA *F-ratio*	ANOVA *df*	ANOVA *p*
Pilots	93	0.462	0.214	0.196	4.823	12.232	2,90	<.001
B/Ns	99	0.558	0.311	0.289	4.122	14.296	3,95	<.001

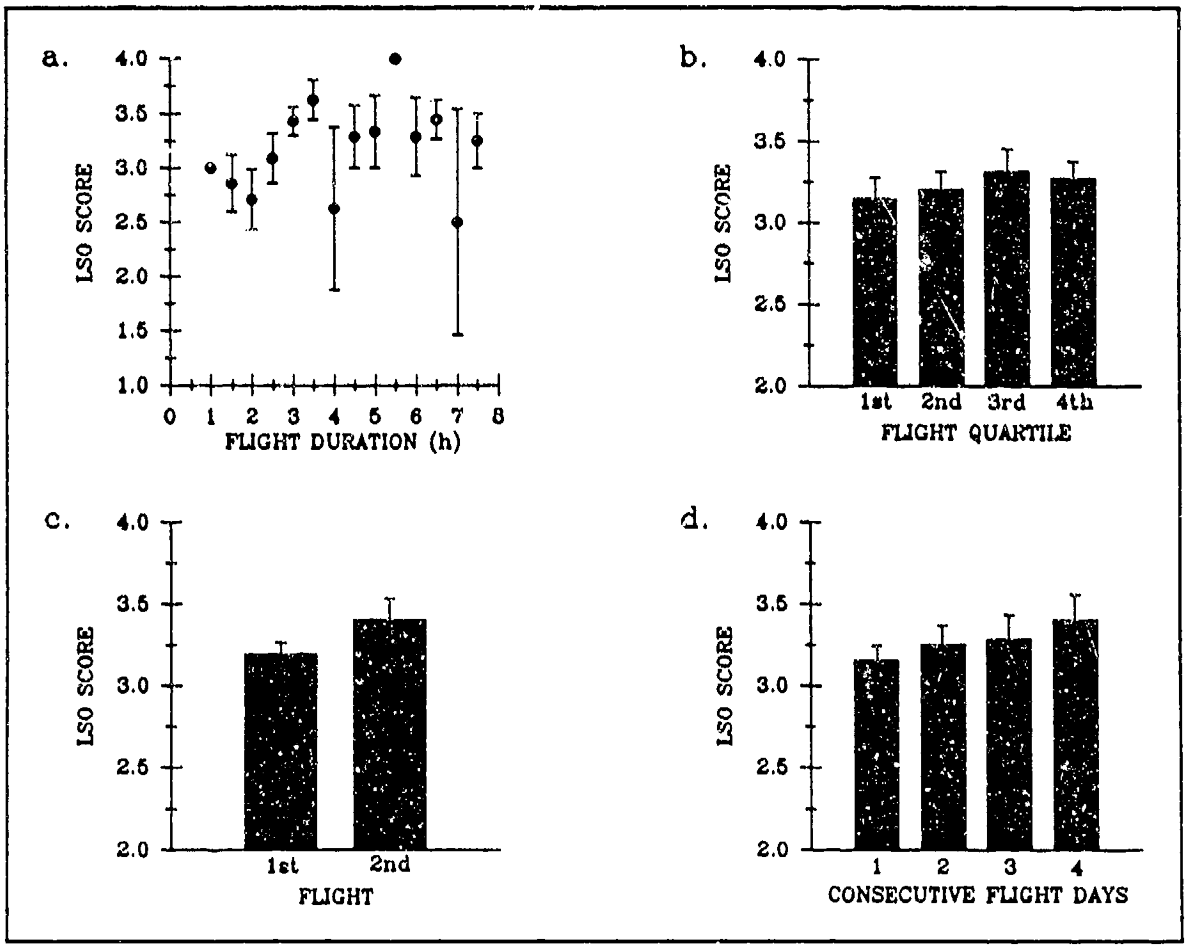


Figure 10. A-6 pilot LSO scores plotted as a function of flight duration (a), flight quartile (b), order and number of flights occurring in a day (c), and consecutive flight days (d).

TABLE 4. A-6 Pilot Multiple Regression and Standard Coefficients.

Variable	Coefficient	Standard error	Standard coefficient	*t*	*p (2 tail)*
Constant	-2.120	2.151	0.000	-0.986	0.327
Duration	1.036	0.259	0.375	4.009	0.001
Flights Per Day	4.765	1.692	0.263	2.816	0.006

TABLE 5. A-6 B/N Multiple Regression and Standard Coefficients.

Variable	Coefficient	Standard error	Standard coefficient	*t*	*p (2 tail)*
Constant	3.809	1.910	0.000	1.994	0.049
Duration	0.743	0.284	0.248	2.615	0.010
Quartile	0.866	0.492	0.184	1.761	0.081
Prior 12 h	-0.276	0.092	-0.293	-3.008	0.003

<u>Summary</u>

During Operation Desert Shield, A-6 aircrew flew primarily midmorning and late-afternoon TRG and TNK flights. With the beginning of Operation Desert Storm, aircrew flew primarily mid-afternoon MSNTNK and TNK missions, as well as late night MSNTNK and STRIKE missions into hostile territory. These late night STRIKE missions often interfered with normal sleeping patterns.

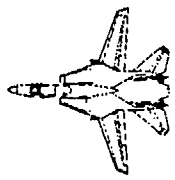
An inspection of the descriptive data revealed that subjective aircrew readiness, as measured by the SSD question on the activity survey, was affected by such variables as 1) the type of mission flown, 2) the duration of the flight, 3) the time of day that a flight occurred, 4) the number and order of flights in a day, 5) the number of consecutive days during which a flight occurred, and 6) the amount of sleep that aircrew received 06, 12, and 18 h before flying. Specifically, those missions that occurred over hostile territory (i.e., MSNTNK and STRIKE) were associated with higher levels of SSD for both pilots and B/Ns. A-6 aircrew SSD increased as flight duration increased and was largest during the fourth flight quartile (0001-0600 h). However, the pattern of results for the remaining three flight quartiles differed for pilots and B/Ns. The number and order of flights in a day only affected pilot SSD with larger SSDs associated with the second flight of the day. For A-6 aircrew, SSD scores were largest following three consecutive days during which a flight occurred. The pattern of results following one, two, and four consecutive days during which a flight occurred varied slightly between pilots and B/Ns. As might be expected, the amount of sleep aircrew obtained before flying also affected SSD. Both aircrews reported consistently lower SSD as the amount of sleep 6, 12, and 18 h before a flight increased.

The LSO grades were much less revealing than SSD. The only consistent relationships were the order and number of flights occurring in a day and the number of consecutive days during which a flight

occurred. Specifically, LSO grades were slightly better on the second flight of the day, relative to the first, and appeared to get progressively better as the number of consecutive days of flying increased up to 4 days.

Using multiple regression techniques, a significant multiple regression was obtained for SSD reported by both A-6 pilots and B/Ns with only slight differences. For A-6 pilots flight duration accounted for the greatest amount of variance in reported SSD, while the amount of sleep 12 h prior to a flight accounted for the greatest amount of variance among A-6 B/Ns. The regression equation derived for SSD reported by A-6 pilots included flight duration and the number and order of flights occurring per day. Likewise, the regression equation derived for SSD reported by A-6 B/Ns included flight duration; however, flight quartile and the amount of sleep obtained 12 h before a flight also added significantly to the A-6 B/N regression equation.

F-14 TOMCAT AIRCREW



Operational Tasking

Like the A-6 aircrew, F-14 aircrew were tasked quite differently during Operation Desert Shield relative to Operation Desert Storm. During Operation Desert Shield, F-14 aircrew flew primarily short-duration TRG flights and combat air patrols (CAPs). Included with the TRG flights, F-14 aircrew flew defense air combat training (DACT), airborne intercept control (AIC), strike fighter training (STRF), maritime air superiority early warning (MASEW), detect to engage (DTE), and extended range CAP (ERC). Because of their relative short-duration and infrequent occurrence, functional check flights (FCF) and post maintenance check flights (PMCF) were also included among the TRG flights, although they do not necessarily involve training. When F-14 aircrew were not participating in TRG flights, they flew CAPs in defense of the carrier battle group. Such flights are routine during peacetime as well as during armed conflict. The F-14 aircrew were also required to participate in both day and night CQ. However, CQ occurred 4 days before the beginning of data collection and was not included in this field study. During normal air operations F-14 aircrew maintained landing proficiency.

Operational tasking of F-14 aircrew differed markedly during Operation Desert Storm. First, the TRG missions prevalent during Operation Desert Shield were discontinued, but, the short-duration CAPs continued throughout the war. Second, several longer duration missions into enemy airspace commenced. Among these were missions using the tactical air reconnaissance pods system (TARP) to assess bomb damage of enemy positions, a duel TARP and fighter escort mission (TRPESC), missions designed to seek and destroy enemy fighter aircraft commonly called MIG sweeps (SWEEP), fighter support of air-to-ground strikes (STRIKE), and CAPs designed to provide fighter support for high value assets (HVUCAP). Many of these missions involved multiple inflight refuelings, which added to their difficulty. Third, all but the short-duration CAPs typically involved flights well into enemy airspace, which subjected the F-14 aircrew to an increased threat relative to missions flown during Operation Desert Shield. Although air-to-air engagements were infrequent, the surface-to-air threat (i.e., SAM and AAA) was formidable.

Descriptive Statistics

The differences in operational requirements during Operation Desert Shield and Desert Storm are depicted in the F-14 flight frequency histograms (Fig. 11). Air operations peaked at approximately 0900 (Fig. 11a) during Operation Desert Shield. However, a second, broader peak was present between 1230 and 2130 h. Although it is tempting to conclude from the broad width of this second peak that flights occurring during this period (1230-2130 h) were of longer duration than those occurring during the first peak, such an interpretation would be erroneous. Rather, the second peak reflects the increase in variability of launch times while the duration of flights remained relatively constant. More importantly, the bulk of the flight activities during Operation Desert Shield occurred within a normal work day (0600-2200).

With the onset of Operation Desert Storm, operational tasking and flight activity changed markedly. As with the A-6 aircrew, flight activity was observed to increase between 2400 and 0600 h. To illustrate this increase in late night/early morning flight activity, separate relative flight frequency histograms were produced for day (Fig. 11b) and night flights (Fig. 11c). The F-14 aircrew flew a variety of flights during the day including CAP, TARP, TRPESC, and SWEEP missions. Peak flight activity occurred at approximately 1300-1400 h (Fig. 11b). This peak coincides with the daytime air-to-air and air-to-ground strikes conducted with other elements of the airwing. A second smaller peak is partially evident between 1800-2300 h, and it reflects the infrequent occurrence of a second flight later that day. A marked increase in night flight activity peaking between 2400-0200 h and continuing through 0730 was evident during Operation Desert Storm. These late night flights would impact heavily on normal sleep patterns. The presence of a second smaller peak between 1230-1900 h reflects the infrequent occurrence of a second daytime mission following the night mission. This second mission was commonly a shorter duration CAP.

The effect operational tasking had on F-14 aircrew subjective combat readiness and reported SSD is depicted in Fig. 12. The profile of responses was very similar for pilots (Fig. 12a) and RIOs (Fig. 12b). In both instances, HVUCAP was associated with the largest SSD followed by STRIKE and SWEEP missions, respectively. An interesting observation is that, like A-6 aircrew, missions with larger mean SSDs were associated with a longer flight duration (Table 6). Parsing out the effect of operational tasking from that of flight duration on reported SSD is problematic and was not possible with these data. However, flight duration did influence reported SSD (Fig. 13). Both pilot and RIO reported SSD increased as a function of increasing flight duration. Only a slight difference was observed between pilot (Fig. 13a) and RIO (Fig. 13b) SSD reports. Pilot mean SSD appeared to increase as a function of flight duration. Curiously, the increase in mean SSD appears almost steplike. Three distinct steps were evident for the figure: 1) approximately 3 h SSD for mission lengths between 1.5 and 2.5 h, 2) approximately 5 h SSD for mission lengths between 3.0 and 5.5 h, and 3) approximately 10 h SSD for mission lengths of more than 6 h. The RIO mean SSD also appeared to increase as a function of mission length, but, a similar steplike increase was not evident from the graph. Rather, RIO mean SSD appeared to increase monotonically, in a manner similar to that of A-6 aircrew reported earlier.

TABLE 6. F-14 Aircrew Flight Duration Descriptive Statistics

	Mission						
Statistics	CAP	TRG	TARP	TRPESC	STRIKE	SWEEP	HVUCAP
Minimum	1.0	1.0	2.0	2.0	2.5	2.5	4.0
Maximum	6.5	5.5	5.0	6.0	6.5	7.0	7.5
Mean	3.500	2.629	3.333	3.750	4.594	4.929	5.000
SD	1.279	0.992	1.110	1.278	1.052	0.806	0.866

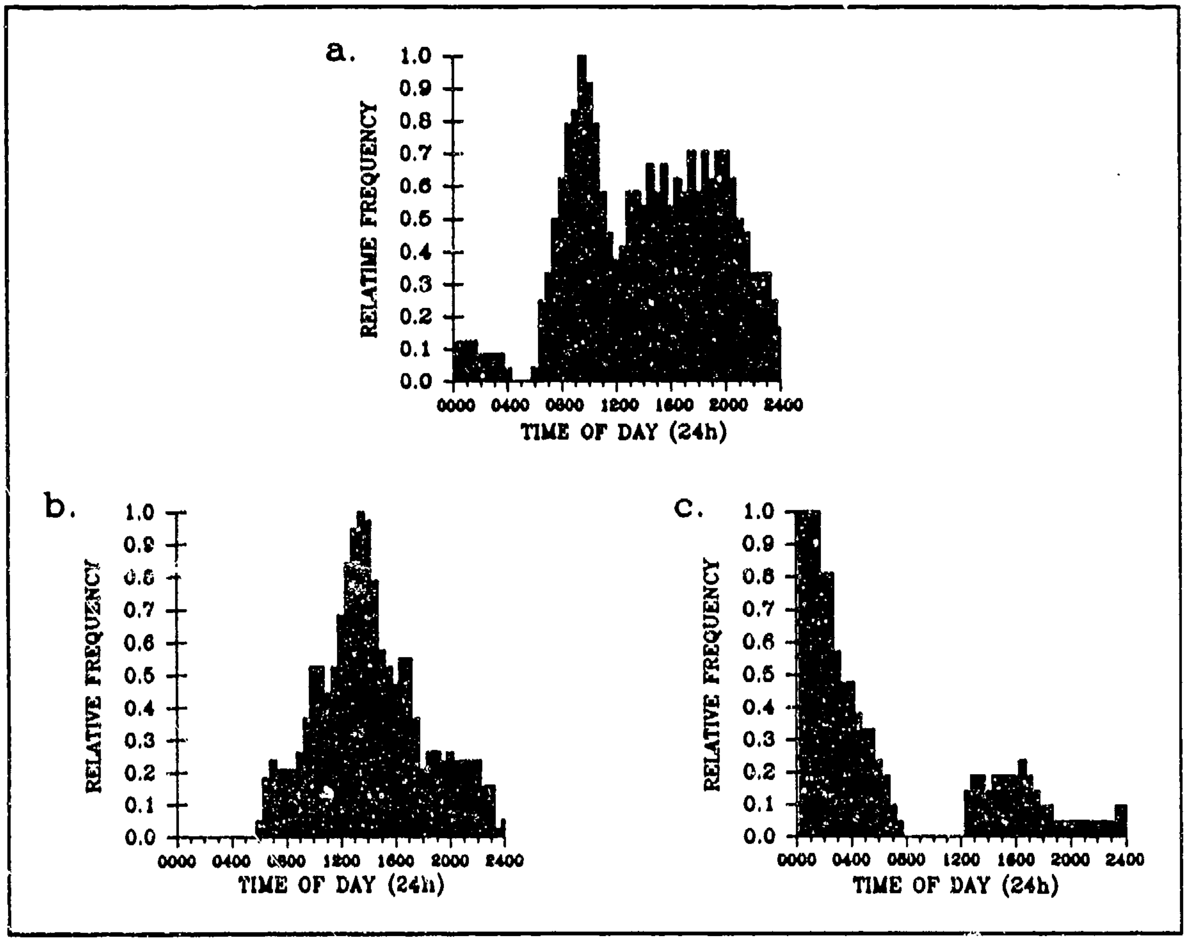


Figure 11. F-14 aircrew relative flight frequency histograms. Operation Desert Shield (a), Operation Desert Storm day flights (b), and Operation Desert Storm night flights (c).

As anticipated, both pilot (Fig. 14a) and RIO (Fig. 14b) mean SSD were observed to vary with the time of day that the flight occurred as indicated by the flight quartile. The F-14 aircrew reported the longest SSD during the 4th flight quartile (0001-0600 h). For both aircrews, progressively shorter SSDs were reported for the 3rd (1801-2400 h), 2nd (1201-1800 h), and 1st (0601-1200 h) flight quartiles, respectively. The only apparent difference observed between F-14 pilot and RIO mean SSD was in the magnitude of aircrew reports. During all four flight quartiles, pilots appear to report slightly longer SSDs than RIOs.

As shown in Fig. 15, F-14 pilots and RIOs were differentially affected by the number and order of flights occurring in a day. Because of the differences observed for A-6 pilots, we also expected that a similar difference would be evident here. Clearly that was not the case. Pilots reported little or no difference in SSD between the first and second flight of the day (Fig. 15a). In contrast, a marked increase in reported SSD was observed between the first and second flights for F-14 RIOs (Fig. 15b), which was again contrary to what was observed for A-6 B/Ns.

Few consistent differences in SSD were reported by F-14 aircrew following up to four consecutive days of flight activity (Fig. 16). Both the F-14 pilot (Fig. 16a) and RIO (Fig. 16b) mean SSD ranged from 4-6 h. Although the RIO' mean SSD tended to increase from day 1 to 3, it decreased by day four. The F-14

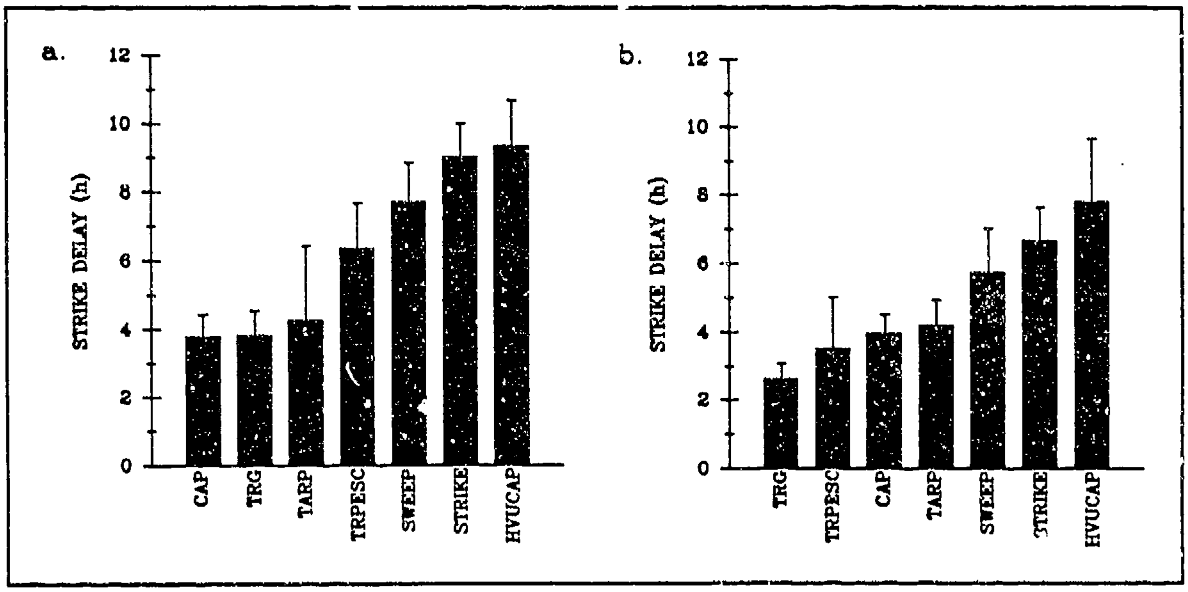


Figure 12. F-14 pilot (a) and RIO (b) mean SSD (+ 1 *SEM*) plotted as a function of mission type.

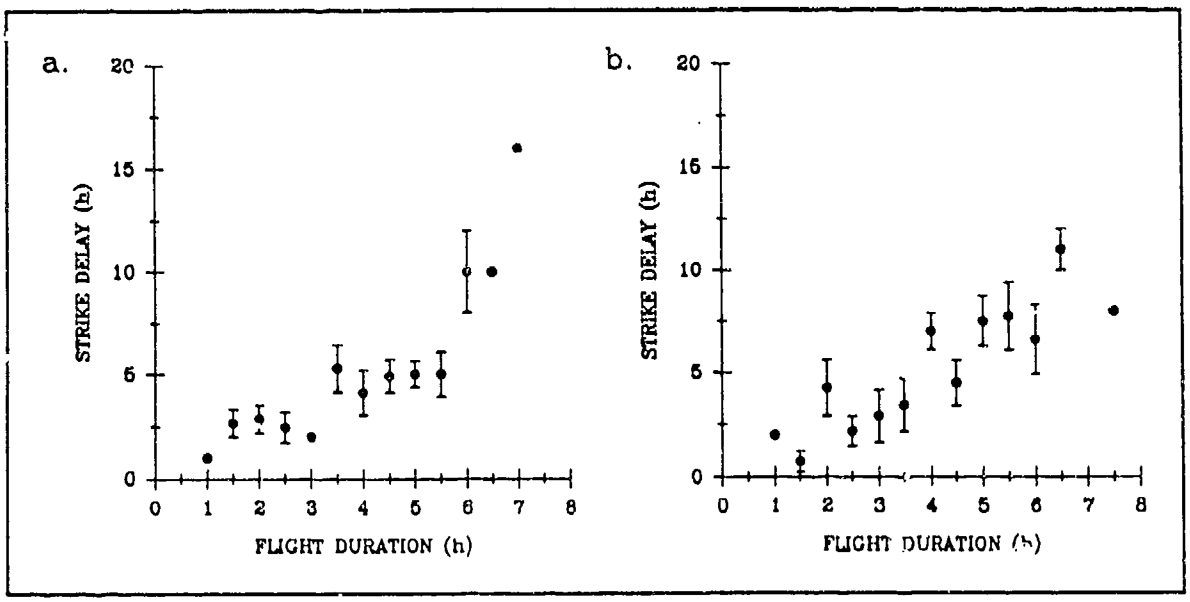


Figure 13. F-14 pilot (a) and RIO (b) mean SSD (± 1 *SEM*) plotted as a function of flight duration.

pilot displayed a similar increase in mean SSD except for day three, where a slight reduction in mean SSD was observed.

The amount of sleep that F-14 pilots (Fig. 17) obtained before they engaged in flight activities appeared to have only modest effects on SSD. A pattern similar to that found with A-6 aircrew was evident, although the slope of the effect was less steep. In essence, F-14 pilots reported less SSD as the amount of time spent sleeping increased when evaluated 6 h (Fig. 17a) and 12 h (Fig. 17b) before a flight. The effect appeared to dissipate 18 h (Fig. 17c) and 24 h (Fig. 17d) before flying. Of note, we found no instances

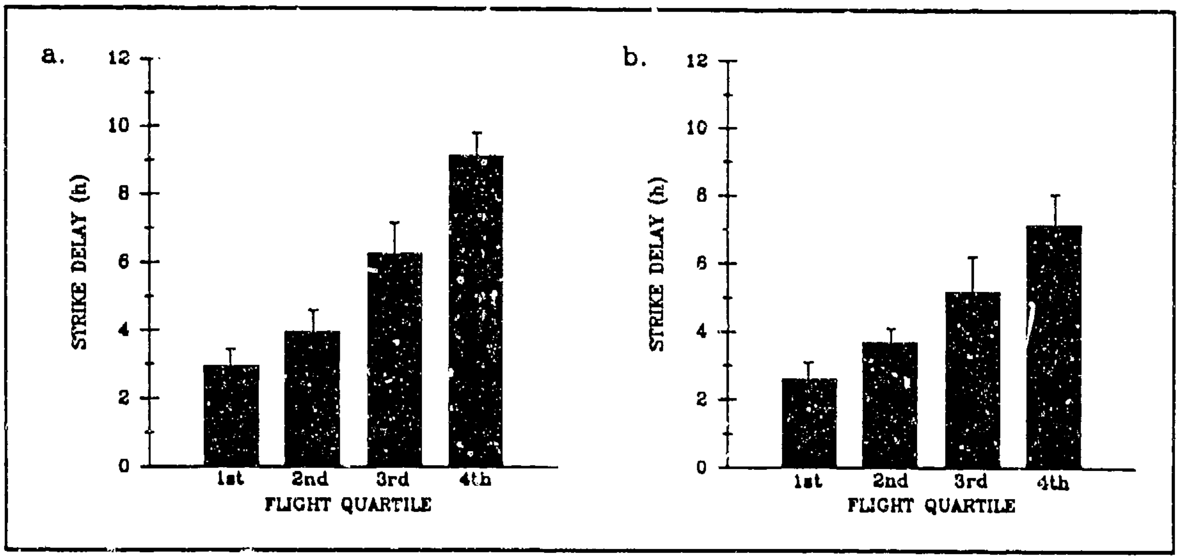


Figure 14. F-14 pilot (a) and RIO (b) mean SSD (+ 1 *SEM*) plotted as a function of flight quartile.

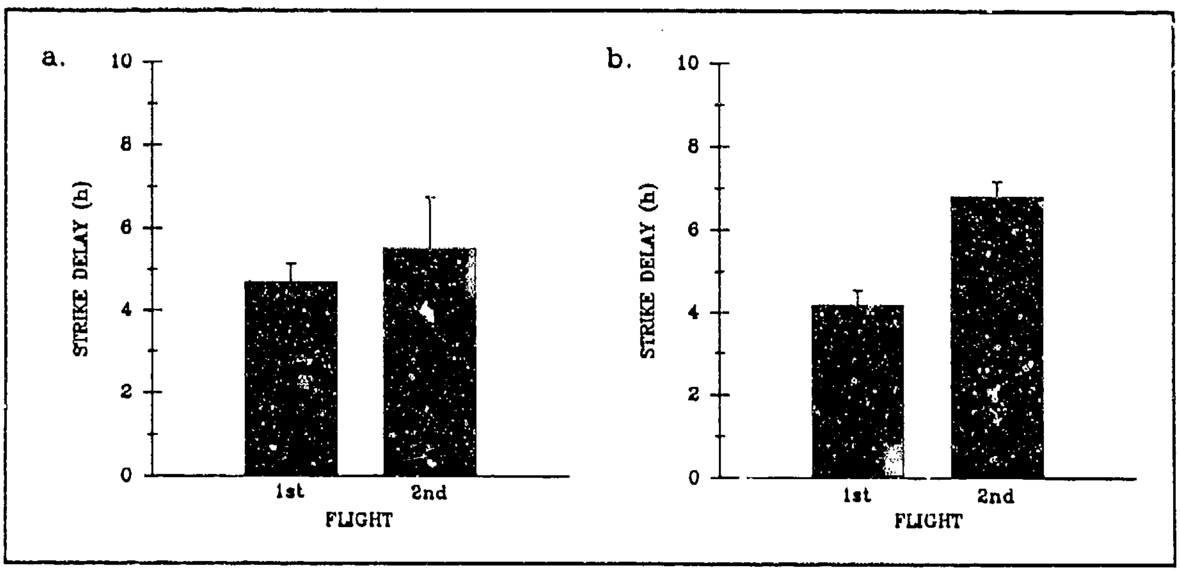


Figure 15. F-14 pilot (a) and RIO (b) mean SSD (+ 1 *SEM*) plotted as a function of the number and order of flights in a day (24 h).

where F-14 pilots obtained less than 3.5 h of sleep in a 24-h period before a flight. Moreover, the mean reported SSD did not exceed 10 h.

The pattern observed with F-14 RIOs was similar to that reported for their pilot counterparts. That is, F-14 RIOs reported less SSD as the amount of sleep increased when evaluated 6 h (Fig. 18a) and 12 h (Fig. 18b) before engaging in flight activities. With few exceptions, F-14 RIOs did not report less than 6 h of sleep in the 24 h before flying. Likewise, in most instances, mean reported SSD did not exceed 12 h, as compared to less than 10 h reported by F-14 pilots.

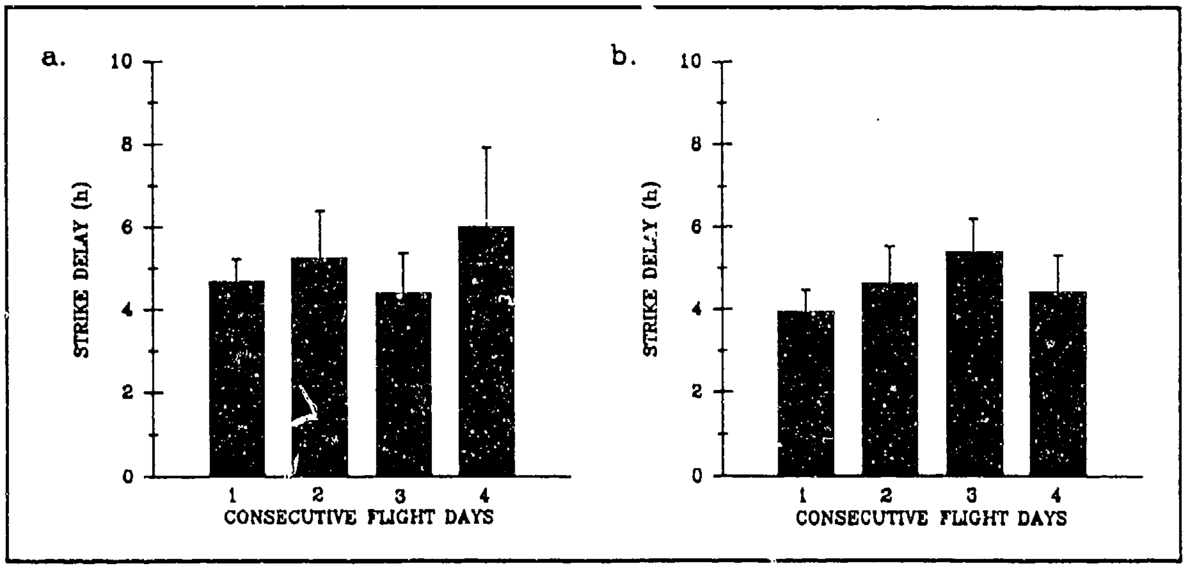


Figure 16. F-14 pilot (a) and RIO (b) mean SSD (+ 1 *SEM*) plotted as a function of the number of consecutive flight days.

We obtained LSO grades assigned to F-14 pilots and compared them to flight duration (Fig. 19a), flight quartile (Fig. 19b), the order and number of flights occurring in a day (Fig. 19c), and consecutive flight days (Fig. 19d). The mean LSO grades did not appear to vary significantly across the range of flight duration reported (Fig. 19a). Mean LSO grades were generally high; 3.0 (*fair pass*) to a 4.0 (*good pass*). The LSO grades did appear related to flight quartile (Fig. 19b). Mean LSO grades peaked during the 1st (0601-1200 h) and 4th (0001-0600) flight quartiles and were progressively lower during the 2nd (1201-1800 h) and 3rd (1801-2400) quartiles, respectively. A further decline in LSO grades was evident between the 1st and 2nd flight of the day (Fig. 19c). The number of consecutive flight days also appeared to affect LSO grades but not until the 4th and 5th consecutive day of flying (Fig. 19d). Curiously, LSO grades obtained during the 4th and 5th consecutive day of flying improved considerably. By the 6th consecutive day of flying, pilot's LSO grades had again returned to levels equivalent to the first three consecutive flight days.

Multiple Regression

The results of the multiple regression analysis are presented in Tables 7, 8 and 9. A significant multiple regression was obtained for F-14 pilots (Table 7). Using the significant regression coefficients presented in Table 8, the multiple regression equation could be represented as follows:

$$SSD_{F\text{-}14\ Pilots} = -2.731 + 1.146\ (\text{Flight duration}) + 1.495\ (\text{Flight quartile})$$

Using this equation, 38.9% of the variance can be accounted for. The predicted variance that could be accounted for using this equation given a new sample from the population is 37.3%. The standard coefficients have been provided in Table 8 to compare the relative contributions of the significant variables. For F-14 pilots, flight duration shows the strongest relationship with SSD followed by the flight quartile. Interestingly, if all else is held constant, F-14 pilots report -2.731 h crew rest implying that they may naturally underestimate their needed crew rest.

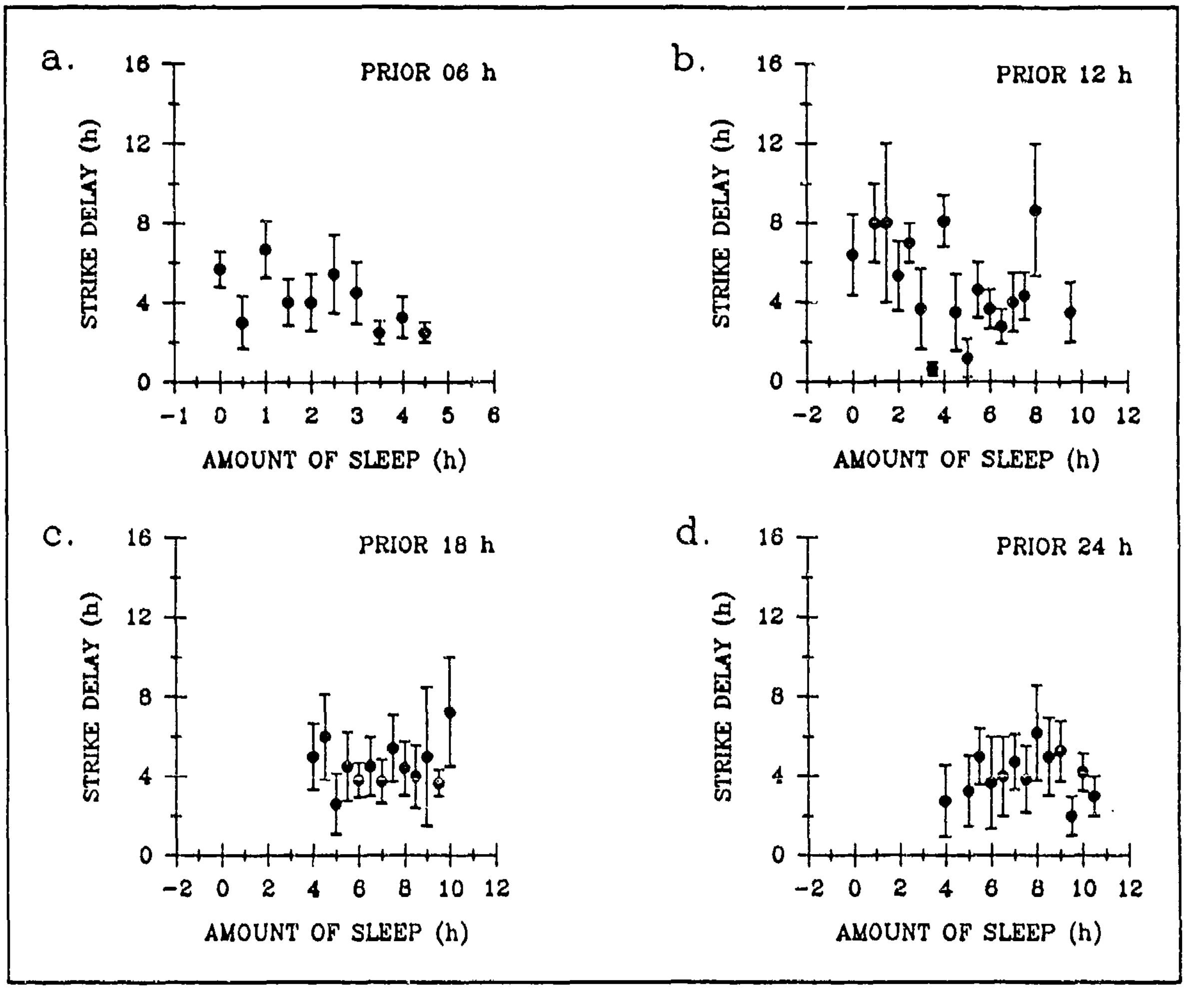


Figure 17. F-14 pilot mean SSD (± *SEM*) plotted as a function of the amount of sleep 06 h (a), 12 h (b), 18 h (c), and 24 h (d) prior to flying.

A significant multiple regression was also obtained for F-14 RIOs (Table 7). Using the significant regression coefficients in Table 9, the multiple regression equation can be represented as follows:

$$\text{SSD}_{\text{F-14 RIOs}} = -4.779 + 1.001\ (\text{Flight duration}) + 1.033\ (\text{Flight quartile}) + 2.891\ (\text{Flight number})$$

By using this equation, the variance accounted for is 43.0%, with the predicted variance that could be accounted for given a new sample from the population being 40.9%. The standard coefficients have been provided in Table 9 to compare the relative contributions of the significant variables. For F-14 RIOs, flight duration shows the strongest relationship with SSD followed by flight quartile and the number and order of flights per day, respectively. Like their pilot counterparts, when all else is equal, F-14 RIOs report needing -4.779 h crew rest. This implies that F-14 RIOs, like F-14 pilots, underestimate their needed crew rest following missions. This should be taken into consideration whenever estimates of crew rest are obtained from highly motivated aircrew.

TABLE 7. F-14 Aircrew Multiple Regression Results.

Aircrew	N	Multiple R	Multiple R^2	Adjusted multiple R^2	S_e	ANOVA		
						F-ratio	*df*	*p*
Pilots	81	0.623	0.389	0.373	3.058	24.798	2,78	<.001
RIOs	83	0.656	0.430	0.409	2.485	19.896	3,79	<.001

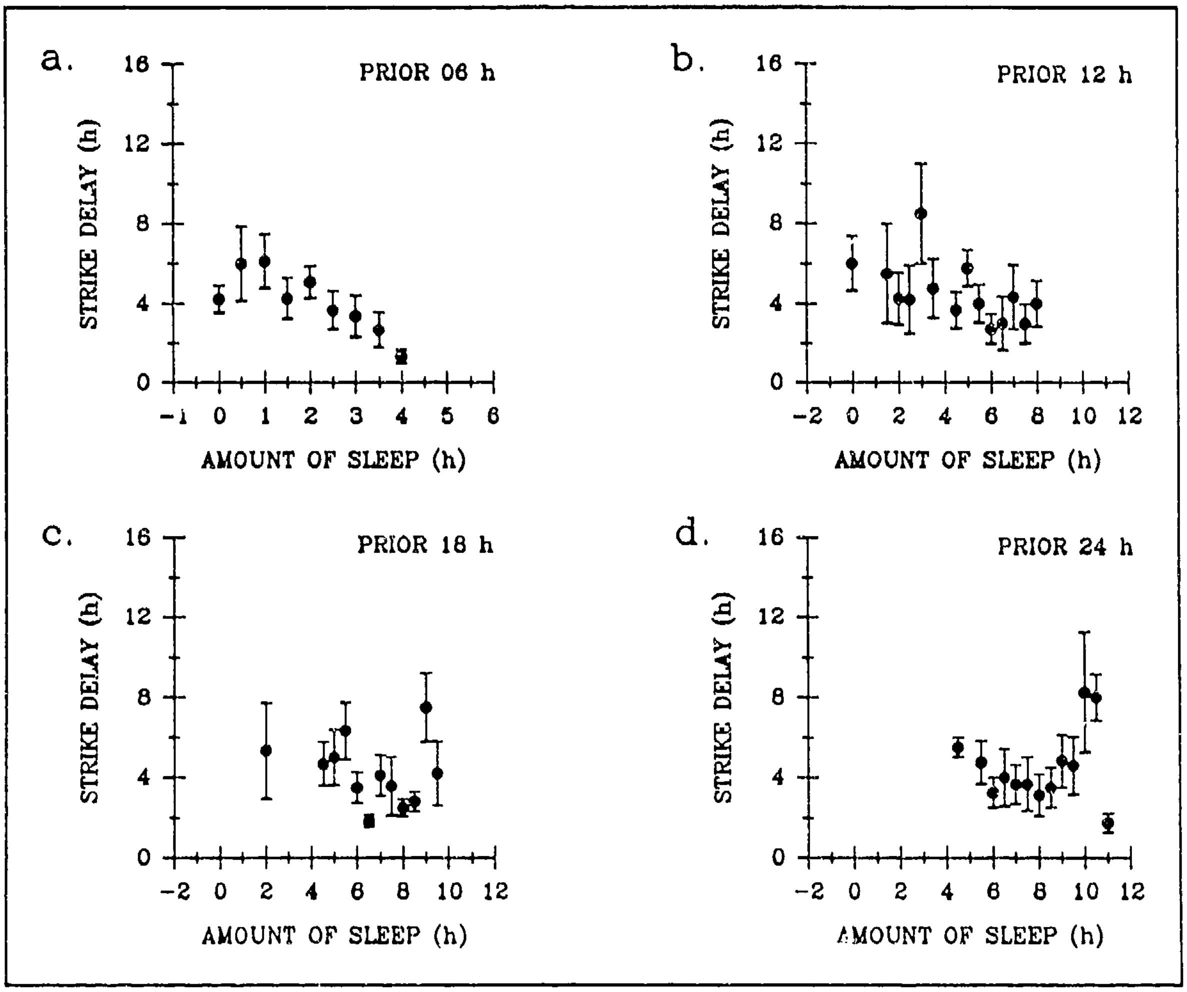


Figure 18. F-14 RIO mean SSD (± *SEM*) plotted as a function of the amount of sleep 06 h (a), 12 h (b), 18 h (c), and 24 h (d) prior to flying.

TABLE 8. F-14 Pilots Multiple Regression and Standard Coefficients.

Variable	Coefficient	Standard Error	Standard Coefficient	*t*	*p (2 tail)*
Constant	-2.731	1.121	0.000	-2.436	0.017
Duration	1.146	0.252	0.418	4.550	0.001
Quartile	1.495	0.377	0.364	3.964	0.001

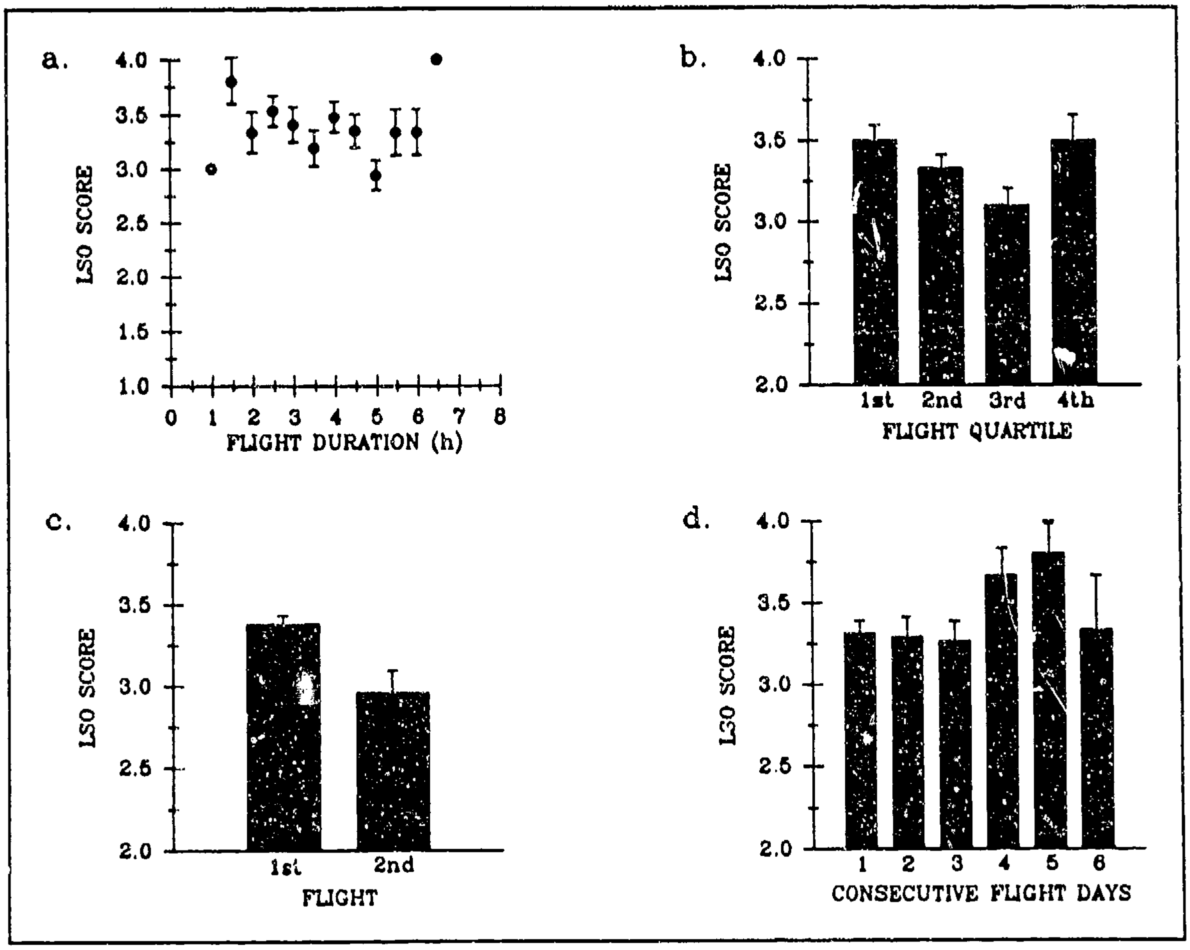


Figure 19. F-14 pilot LSO scores plotted as a function of flight duration (a), flight quartile (b), order and number of flights occurring in a day (c), and consecutive flight days (d).

TABLE 9. F-14 RIOs Multiple Regression and Standard Coefficients.

Variable	Coefficient	Standard Error	Standard Coefficient	*t*	*p (2 tail)*
Constant	-4.779	1.528	0.000	-3.128	0.002
Duration	1.001	0.201	0.449	4.991	0.001
Quartile	1.033	0.284	0.327	3.641	0.001
Flights Per Day	2.891	1.173	0.214	2.466	0.016

Summary

During Operation Desert Shield, F-14 aircrew flew primarily mid-morning and late-afternoon TRG and CAP missions well within a normal work day. Mission tasking during Operation Desert Storm was quite different; F-14 aircrew flew primarily mid-afternoon and late-night missions. A variety of combat missions into enemy airspace were flown, including: CAP, TARP, TRPESC, STRIKE, SWEEP, and HVUCAP missions. The late-night missions occurred at a time when aircrew would normally be asleep, and impacted heavily on normal aircrew work/rest schedules.

Subjective aircrew readiness, as measured by the SSD question on the activity survey, was influenced by several of the study variables: 1) the type of mission flown; 2) the duration of the flight; 3) the time of day that a flight occurred; 4) the number and order of flights in a day; 5) the number of consecutive days during which a flight occurred; and 6) the amount of sleep that aircrew received 6 and 12 h before flying. Those missions during Operation Desert Storm that included flights over hostile territory exposing aircrew to additional threats (TRPESC, SWEEP, STRIKE, and HVUCAP) were associated with larger SSDs than local flights in defense of the carrier battle group and those occurring during Operation Desert Shield (CAP and TRG). Moreover, pilots reported slightly higher SSDs as a function of operational tasking than did their RIO counterparts. Pilot and RIO SSDs were also influenced by the duration of the flight. Reported SSD increased as a function of increasing flight duration. Pilot SSD increased in a steplike fashion while RIOs increased in a more linear manner. In both instances, the rate of increase was less than that observed for A-6 aircrew. Both pilots and RIOs showed a consistent increase in reported SSD as the flight quartile increased from the first to the fourth quartile. However, only RIOs reported differences between the first and second flight in a day, with the second flight being associated with larger SSDs. A much more erratic pattern of responses was obtained for SSDs associated with the number of consecutive flight days. Pilots reported an increase in SSD between consecutive days one and two, followed by a slight decrease on day three and an increase on day four. The RIOs reported a progressive increase in reported SSD over the first three consecutive days, followed by a decrease on consecutive day four. The amount of time F-14 aircrew spent sleeping before a flight appeared to influence reported SSD in much the same manner as it did A-6 aircrew. As the amount of time spent sleeping increased 6 h and 12 h before a flight, pilot and RIO SSD decreased. No consistent patterns were evident 18 h and 24 h before a flight.

Generally, LSO grades assigned to F-14 pilots were very high. Several consistent relationships were evident when the LSO grades were related to flight quartile, the number and order of flights in a day, and consecutive days during which a flight occurred. For example, LSO grades decreased progressively across the first three flight quartiles (i.e., 0601-1200 h, 1201-1800 h, and 1801-2400 h), but, returned to first quartile levels by flight quartile four (0001-0600). Furthermore, LSO grades were also influenced by the number and order of flights in a day, with lower scores being reported during the second flight of the day. A slight

increase in LSO grades was also evident following four and five consecutive days during which a flight occurred compared with the first three consecutive flight days. Flight duration did not consistently affect LSO grades.

Using multiple regression techniques, a significant multiple regression was obtained for SSD reported by both F-14 pilots and RIOs with only slight differences. The regression equation associated with F-14 RIOs included flight duration, flight quartile, and the number and order of flights occurring per day. Likewise, the regression equation associated with F-14 pilots included flight duration and flight quartile. The number and order of flights occurring per day, however, did not contribute significantly to the multiple regression equation for the F-14 pilots.

DISCUSSION

A unique feature of this field study is that data were obtained from the same fleet aviators during both peace-time (Operation Desert Shield) and combat (Operation Desert Storm) operations. Therefore, we were able to document any modifications that were made to work/rest schedules as operational tasking shifted. More importantly, we could evaluate the impact this shift in tasking had on subjective aircrew readiness and landing performance. The operational tasking of the A-6 and F-14 squadrons changed significantly as they transitioned from Operation Desert Shield to Operation Desert Storm. During Operation Desert Shield, the majority of flights in both squadrons occurred during a normal work day (0700-2000 h) with little or no impact on normal sleep patterns. The operational tasking during this period consisted primarily of routine TRG missions flown by both squadrons. Additional short-duration TNK and CAP missions were flown by A-6 and F-14 aircrews, respectively. As Operation Desert Storm commenced, operational tasking changed markedly. As expected, all TRG flights ceased. In addition to the TNK and CAP missions still flown by the two squadrons, a wide range of combat missions was flown. For the most part, A-6 aircrew flew long-range MSNTNK and STRIKE missions well into enemy territory. These long-range missions were of considerable duration (4-7 h) and met with a significant air-to-air threat initially and surface-to-air threat throughout the war. Moreover, these MSNTNK and STRIKE missions occurred during the late night and early morning hours, a period when aircrew would normally be asleep.

Like their A-6 counterparts, F-14 aircrew mission tasking also differed markedly from that assigned during Operation Desert Shield. The F-14 aircrews were tasked with additional TARP, TRPESC, SWEEP, STRIKE, and HVUCAP missions. With few exceptions, these missions were flown over enemy territory, exposing the aircrew to a substantial threat. Like the strikes flown by the A-6 aircrew, many of these missions were flown during late night and early morning hours, a time when aircrew would normally be asleep.

The impact operational tasking had on work/rest schedules and sleep patterns is addressed elsewhere (18); however, the effect of operational tasking on aircrew readiness and landing performance was evaluated here. Subjective aircrew readiness, as reported by aircrew using the SSD question on the daily activity survey, was affected by several flight variables: 1) the type of mission flown, 2) the flight duration, 3) the time of day that the flight occurred, 4) the number and order of flights in a day, and 5) the number of consecutive days during which a flight occurred. In addition, the amount of sleep that aircrew received 6, 12, and to a lesser extent, 18 h before a flight influenced aircrew SSD.

As expected, the type of mission flown influenced reported SSD by A-6 and F-14 aircrews. Missions that included flights over hostile territory (for A-6 aircrew these included MSNTNK and STRIKE missions, for F-14 aircrew these included TARP, TRPESC, SWEEP, STRIKE and HVUCAP missions) were associated with a longer SSD than those flights occurring during Operation Desert Shield or less threatening flights during Operation Desert Storm. However, much of the increase in reported SSD previously attributed to the type of mission flown may be a function of other flight and work/rest variables. For example, initial

data analysis revealed that the type of mission flown was strongly related to mission duration. Specifically, those missions associated with longer reported SSDs were also of longer mean duration. Furthermore, many of the flights over enemy air space were of long duration and required multiple inflight refuelings. That these were long-duration flights should not be attributed entirely to the specific mission type. Rather, the proximity of the carrier battle group to the target often dictates the length of the mission. In this instance, aircrews flew several hundred miles from the northern Red Sea to targets in western and central Iraq. However, each mission type was associated with a broad range of flight durations, many of which were of relatively short-duration. Unfortunately, we had no specific information available to explain the observed range in flight duration for some of the combat missions. A plausible explanation is that a wide range of targets of varying distance from the aircraft carrier were assigned. For example, STRIKE missions flown into southwestern Iraq were much closer to the carrier battle group located in the northern Red Sea than those along central and eastern Iraq. This may account for the range in flight durations seen in the STRIKE missions flown by A-6 aircrew (2.5-9.5 h). In fact, virtually all mission types were associated with a wide range of flight durations. Because of the range of flight durations among mission types, it is probably more appropriate to examine the effect flight duration had on reported SSD independent of the mission flown. When the data are evaluated in this manner, reported SSD increases as a function of flight duration for both aircrews. The only difference is in the profile of the function. For A-6 pilots and B/Ns and F-14 RIOs, reported SSD appeared to increase monotonically with increasing flight duration, while reported SSD from F-14 pilots appeared to increase in a steplike fashion.

The type of mission flown was also related to the time of day that a flight occurred. During Operation Desert Shield, nearly all the flights transpired during a normal working day. In contrast, with the onset of Operation Desert Storm, many of the combat missions were flown during the late night and early morning hours, a time when aircrew would normally be asleep. Furthermore, those missions that occurred late at night were often the same long-range STRIKE, MSNTNK, TARP, TRPESC, SWEEP, and HVUCAP missions that were associated with longer flight durations and greater reported SSDs. In fact, the STRIKE missions flown by A-6 aircrew were exclusively night missions. As expected, both aircrews reported much longer SSDs during the fourth flight quartile (0001-0600 h). This is consistent with other findings involving aircraft mishap rates in the U.S. Navy. As stated earlier, Borowsky and Wall (4) found that Class A F/FR mishap rates were significantly related to the time of day that the flight originated. Flights that originated between 2400 and 0600 were associated with the highest occurrence of mishaps. Borowsky and Wall attributed much of this increase in mishap rates to disruptions in sleep-wakefulness cycles and circadian desynchronization. It is feasible that flying missions while in a circadian trough or when aircrew might otherwise be asleep increases feelings of fatigue, thereby putting aircrew at higher risk than if the same mission were flown during the day. Note that a large part of the data obtained here was during combat operations in a highly threatening environment where the risk of death was clearly a factor. This may have played an additional role in the elevated SSDs reported by aircrew during the fourth quartile. However, many of the combat missions flown by the F-14 aircrew and some of the missions flown by A-6 aircrew occurred during the day. Even so, there was no evidence that reported SSDs associated with flights during the day (i.e., the first and second flight quartiles) was equal to, or greater than, SSDs reported at night. Such results lend additional support to the influence of circadian effects on aircrew readiness.

Consistent with previous findings (4-6,14), the number and order of flights in a 24-h day influenced reported SSD. Both aircrews reported consistently longer SSDs following the second flight in a 24-h period. As discussed earlier, this observation may be confounded with the time of day of the flight, as in nearly every instance the second flight occurred during the third and fourth flight quartiles. However, if this confound existed, it should be evident in all aircrew. This was not the case here. The largest difference between first and second flights in a day occurred with the A-6 pilots. Curiously, their B/N counterparts reported little or no difference between the first and second flight. This came as a surprise, considering they were flying the same missions. Possibly, the tasking within the aircraft, and therefore the level of fatigue experienced by the aircrew in the A-6, is sufficiently distinct to produce the observed differences. Why then, were similar differences not observed among the F-14 pilots and RIOs? In fact, a reversal of the effect was observed for

F-14 pilots and RIOs, with RIOs showing the greatest difference between flights and pilots demonstrating little or no difference. A more thorough analysis of the role each aviator plays in the A-6 and F-14 is needed to answer this question.

The effect that the number of consecutive flight days has on aircrew readiness and SSD is much less clear than the other variables previously discussed. Recall that Krueger et al. (14) demonstrated that helicopter pilots who worked 20-h workdays responded more passively and created more errors of omission after four consecutive days of flying. In our study, A-6 pilots and B/Ns reported much higher SSDs after three consecutive days of flying, but lower SSDs after four consecutive flight days. One plausible explanation for this paradoxical drop in SSDs after four consecutive flight days may be a function of the way aircrew were scheduled by the operations officer and the type of missions assigned. Aircrew scheduling and mission tasking were extremely well managed during the war. The abundance of assets in the theater precluded the need for <u>all</u> aircrews assigned to a squadron to fly long-duration missions into enemy territory every night. Rather, squadron commanding officers and operations officers could rotate their aircrews between long-duration combat missions and shorter duration TNK missions. A larger percentage of short-duration, local TNK missions were flown after four consecutive flight days, than after three, and presumably contributed to the observed decrease in reported SSD. A less consistent pattern of results was obtained from the F-14 aircrew, making any interpretation problematic.

The amount of sleep 24 h before a flight may influence aircrew performance (4). We investigated the amount of sleep 6, 12, 18, and 24 h before a flight and the relationship with reported SSD. The results obtained for both aircrews were mixed. When a relationship was evident, reported SSD was inversely related to the amount of time spent sleeping before a flight, especially for A-6 aircrew 12 and 18 h before a flight, and for F-14 aircrew only 06 and 12 h before a flight. However, any conclusions derived from these results are much more complex than the data would suggest. First, due to the limited sample size, we were unable to separate the effect many of the flight variables had on SSD (i.e., mission type, flight duration, the number and order of the flights in a day, and the flight quartile) from the amount of sleep before a flight. Many of these variables influence reported SSD, but the extent to which our results can be attributed to them, and how much can be attributed to the amount of sleep before a flight is difficult to assess. Second, as Borowsky and Wall (4) point out, aircrew assigned late night missions (2400-0600 h) may actually attempt to sleep earlier in the day (e.g., 1600-2000 h). Even so, the quality of that sleep, because it occurs at a circadian peak, may be somewhat less than restful. Nonetheless, it is recorded as sleep on the activity survey and may bias some of the findings. Third, the bulk of the data was obtained from well-rested aircrew (18). The results may have been considerably different had the aircrew been more fatigued. None of these considerations are meant to lessen the importance of the results, as much as they are a call for further investigations in this area.

These findings have enabled us to answer many of the operational questions we listed earlier. The first operational question was, "**What specific variables affect aircrew readiness?**" Our data suggest that at a minimum, such variables as the flight duration, the time-of-day of a flight, the number and order of flights in a day, the number of consecutive days during which a flight occurred, and the amount of sleep before flying all influence subjective readiness. However, many less easily measured variables such as stress, operational demands within the cockpit, physical fitness, and others were not directly investigated here and may all contribute substantially.

The second operational question was, "**How does the duration of a flight influence aircrew readiness?**" In other words, had the aircraft carrier been closer to the target and the missions of shorter duration, would the longer SSDs associated with these missions still have been reported? The data obtained here indicate that flight duration, more than mission type, influences reported SSD. It is plausible that had the aircraft carrier been nearer the targets, shorter SSDs would have been reported.

The third operational question was, "**Does aircrew readiness fluctuate with the time-of-day that a flight occurs?**" Our results indicate that it does. Flights occurring at a time when aircrew would normally be asleep (2400-0600 h) increased subjective feelings of fatigue and SSD. Given this, what would the impact of these missions have been on reported SSD if the flights had all been flown during a normal working day (0700-2000 h)? It is possible that had all missions been flown during a normal working day, that reported SSD may have been notably lower.

The fourth operational question was, "**How would aircrew have been affected had they been required to fly multiple sorties each day over several days as might be expected in a long-duration contingency operation or an Eastern European war scenario?**" The answer to this question is much more hypothetical. From the perspective of squadron operations, this was an extremely well-managed war. Even so, multiple sorties and cumulative flight days did adversely affect reported SSD. In an operation with fewer forces and in similar conditions where around the clock operations were required over several days, considerably longer SSDs could have been reported. Such a scenario would have presumably occurred had Iraqi forces invaded Saudi Arabia shortly after the invasion of Kuwait. Had this occurred, the USS INDEPENDENCE was the only aircraft carrier in the vicinity and may have been called upon to launch strikes against Iraq. We suspect that aircrews aboard the USS INDEPENDENCE would have reported very high SSDs as hostilities continued, much higher than those seen aboard the USS AMERICA in this study.

The fifth operational question was, "**What is the necessary amount of time aircrew should sleep before flying a combat mission?**" This question is too complex to answer given the data obtained in this study. Clearly, some requisite amount of crew rest is needed before flying a combat mission. However, many variables such as mission type, time-of-day of the mission, mission duration, and other variables enter into any intelligent answer. Unfortunately, a precise answer is beyond the scope of these data (see (19) for a thorough discussion of this issue).

Questions such as these are operationally significant and academically interesting; however, the reality of the situation is that combat is often dictated by situations beyond the control of operations officers and senior mission planners. To suggest that all missions be flown during ideal conditions (i.e., only one mission be flown every other day so that aircrew obtain adequate sleep, and that the mission be of short duration and occur during a normal working day) is simply not feasible. Therefore, given that many of these variables cannot be directly controlled, the sixth operational question and a specific aim of this study was, "**... to identify any variables that would aid in the prediction of aircrew readiness.**" Toward this end, separate multiple regression equations were calculated for A-6 pilots, A-6 B/Ns, F-14 pilots, and F-14 RIOs. A significant multiple regression was obtained for each group. As anticipated given the descriptive data presented earlier, combinations of variables such as flight duration, time of day of the flight (i.e., flight quartile), number and order of flights in a day, and amount of sleep 12 h before a flight contributed significantly to the variance accounted for in the multiple regression equations. In all but A-6 B/Ns, flight duration accounted for the largest amount of the variance in reported SSD. The amount of variance accounted for by the flight quartile, the number and order of flights in a day, and the amount of sleep 12 h before a flight varied with the group investigated. Other variables such as consecutive days during which a flight occurred and the amount of sleep 6, 18, and 24 h before a flight did not contribute significantly to the multiple regression equations.

Multiple regression equations such as those generated here may prove particularly helpful to senior mission planners, squadron operations officers, and schedules officers when assigning aircrew to specific missions. For example, using the equation derived for A-6 B/Ns, subjective aircrew readiness can be predicted for a B/N given the duration of the flight, the flight quartile during which it will occur, and the amount of sleep that the B/N would obtain 12 h before the flight. Recall that the equation derived for A-6 B/Ns was:

$$\mathbf{SSD}_{\mathbf{A\text{-}6\ B/Ns}} = \mathbf{3.809 + 0.743\ (Flight\ duration) + 0.866\ (Flight\ quartile) - 0.276\ (sleep\ 12\ h\ before\ flight)}$$

If the B/N were assigned a 6-h mission to be flown from 2400-0600 h and had obtained 2 h of sleep in the period 12 h before launch, the following equation would predict the amount of delay before a combat strike could be flown again:

$$SSD_{A-6\ B/N} = 3.809 + 0.743\ (6\ h) + 0.866\ (4) - 0.276\ (2\ h) = 11.179\ SSD$$

In this instance, knowing flight duration, flight quartile, and the amount of sleep obtained 12 h before the flight, an operations officer could predict 11.179 h of crew rest before a second strike could be flown in the opinion of the B/N.

Although the regression equations derived here are tempting to use in every combat situation, we note that the equation is only as good as the data used to derive it. Thus, using these equations in a much more intense and fatiguing contingency operation may not be appropriate. This is not to imply that regression equations such as these are not useful; they do provide a metric to evaluate aircrew. Regression equations may provide senior mission planners and operations officers with an additional tool to evaluate aircrew assigned to them, but they should not be used as a sole determinant of aircrew readiness. The nature of military operations often requires aircrew to fly even when they are fatigued. In these instances, such equations may prove useful in predicting which aircrew are at risk in the cockpit due to fatigue and stress. Also, flight surgeons might benefit from such equations when deciding whether or not the introduction of a pharmacologic countermeasure to aircrew fatigue is warranted. Most importantly, by identifying when aircrew are at risk, regression equations may provide a useful means of eliminating or reducing the number of aircrew-related flight mishaps such as those described by Borowsky and Wall (4).

Pilot landing performance as measured by LSO grades yielded mixed results. We were generally unable to replicate previous findings in which landing performance was significantly degraded during night, relative to day, recoveries (8,11). If there were any differences in day versus night recoveries, they were in the opposite direction. At least for F-14 pilots, landing performance improved during the fourth flight quartile (0001-0600 h) relative to the second (1201-1800 h) and third (1801-2400 h) flight quartiles. We note that anecdotal reports from LSOs assigned to the USS SARATOGA (CV-60) during Operation Desert Storm indicate that they were more lenient when assigning LSO grades to pilots returning from combat. This may have artificially inflated LSO grades of 3 (*fair pass*) to 4 (*good pass*). Considering that the USS AMERICA and USS SARATOGA were assigned to the same operating area during the war and their aviators were given essentially the same tasking, it is not improbable that the LSOs aboard the USS AMERICA took the same approach when grading the landing performance of aviators returning from combat. If the LSOs aboard the USS AMERICA indeed graded more leniently than usual, our landing performance results would be suspect.

Another explanation is plausible. Using the workload classification of Brictson (8), aircrew tasking during Operation Desert Shield would be considered as zero to moderate cumulative workload while workload during Operation Desert Storm would be considered as moderate to high cumulative workload. Although landing performance was consistently poorer at night, relative to day, throughout Brictson's study, both night and day landing performance benefitted from the increase in operating tempo and landing practice during the high-workload condition. Therefore, if the LSO grades were inflated due to the high tempo of combat operations and not as a result of more lenient LSO grading policies, then the data reported here can be considered valid. When LSO grades from both the A-6 and F-14 pilots are plotted against consecutive flight days, LSO grades increase as the number of consecutive flight days increases. These data support previous findings regarding cumulative practice effects on landing performance and may be valid. Still, the results should be accepted with some degree of caution because the assignment of landing grades is subjective (although attempts have been made at standardization among LSOs through the use of objective criteria and formal training) and are therefore open to bias.

An alternative to analyzing the LSO grades would be to analyze the LSO comments associated with the grades. Approximately 100 different comments can be assigned by LSOs as detailed in NAVAIR 00-80T-104. They include such things as altitude corrections, speed, and deviations off course and glide slope. Our discussions with LSOs aboard the USS SARATOGA revealed that even if LSO grades were assigned more leniently during the Persian Gulf war, the LSO comments were still accurately recorded. An analysis of LSO comments would be more appropriate, and future investigations of this type should focus on LSO comments rather than the grades. Unfortunately, we did not have access to the LSO comments at the time of this report.

Although the temptation is to extrapolate our findings to all aviators in most situations, we do not recommend doing so. Rather, we suggest that the results here be considered with those from fleet training exercises and other contingency operations to obtain an estimation of aircrew readiness. In particular, fleet training exercises and contingency operations provide opportunities to further validate and update the multiple regression equations derived here. When used alone, our data should serve only as an initial step in identifying variables that could influence aircrew readiness and landing performance. In conjunction with existing experiential and qualitative judgments by individuals charged with determining aircrew readiness--group commanders, senior mission planners, and flight surgeons--our data should prove useful in improving the safety of flight.

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